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ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

7 RUE ANCELLE 92200 NEUILLY SUR SEINE FRANCE

AGARD ADVISORY REPORT No.296

Mission Planning Systems for Tactical Aircraft (Pre-Flight and In-Flight)

Systèmes de Planification des Missions pour Avions Tactiques (Avant Vol et en Vol)

NORTH ATLANTIC TREATY ORGANIZATION

Distribution and Availability on Back Cover

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This report has been prepared at the request of the Avionics Panel and Aerospace Medical Panel of AGARD.

North Atlantic Treaty Organization

Organisation du Traité de l'Atlantique Nord

91-04566

The Mission of AGARD

According to its Charter, the mission of AGARD is to bring together the leading personalities of the NATO nations in the fields of science and technology relating to aerospace for the following purposes:

- Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community;

- Providing scientific and technical advice and assistance to the Military Committee in the field of aerospace research and development (with particular regard to its military application);

- Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;

- Improving the co-operation among member nations in aerospace research and development;

- Exchange of scientific and technical information;

- Providing assistance to member nations for the purpose of increasing their scientific and technical potential;

- Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field.

The highest authority within AGARD is the National Delegates Board consisting of officially appointed senior representatives from each member nation. The mission of AGARD is carried out through the Panels which are composed of experts appointed by the National Delegates, the Consultant and Exchange Programme and the Aerospace Applications Studies Programme. The results of AGARD work are reported to the member nations and the NATO Authorities through the AGARD series of publications of which this is one.

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Preface

The concept of planning a mission for a military aircraft is probably as old and well established as that of the military aircraft itself, but until recently the methodology and technology associated with mission planning had received only limited attention from scientists and engineers. The last few years have, however, seen a marked increase in the attention given to mission planning both by the users, who are demanding improved facilities, and by the suppliers, who are able to provide increasingly more capable systems. As a result, the Air Forces of many of the NATO countries are procuring new and advanced mission planning systems that have capabilities far in advance of those previously available.

The principal reason for this change is to be found in the way information technology is being applied throughout the airborne and on-ground elements of the Air Forces. Modern military aircraft are equipped with avionics suites in which the individual functions of navigation, flight control, communication, etc. are interconnected to form a single coherent system having at least some of the characteristics of intelligence. On the ground, information on terrain, enemy and friendly forces, targets, etc. is correlated and distributed in networks to become available at ground stations or ships where it may be needed for planning purposes. Prior to the start of a mission it is necessary to initialize the avionics system by providing to it a large amount of data from the on-ground network, and this forms one of the most important functions of the modern mission planning system. Included in the data to be loaded are the plans of the specific mission and the generation of these, that typically involves the aircrew, introduces the idea that the planning process also includes a significant element of review and rehearsal. Modern mission planning systems use the new techniques of information technology to streamline the whole process of planning, review, rehearsal, data filtering and data transfer.

AGARD Joint Working Group 15 was established to review mission planning systems and to consider how they are likely to evolve in the future. Its terms of reference specifically included in-flight mission planning and mission rehearsal, and specified a two-phase program of study. This advisory report covers the work of Phase One only.

The Working Group's members met five times during Phase One. The Group's work was considerably assisted by presentations and demonstrations provided by organizations in host countries. Additionally, some members of the Group attended a meeting organized by NAFAG where problems of interoperability of mission planning systems were discussed. The value of the contributions thus made by many individuals is gratefully acknowledged.

The Working Group's studies during Phase Two will concentrate on specific areas in which rapidly changing technologies are expected to result in major new capabilities in system performance. These will be described in a subsequent report. During this phase the Group will continue its participation in the further NAFAG activities on mission planning system interoperability.

Préface

Le concept de la planification des missions est sans doute aussi ancien et aussi connu que celui de l'avion militaire lui-même, mais jusqu'à ces derniers temps la communauté scientifique n'avait prête qu'une attention limitée à la méthodologie et la technologie associées à la planification des missions. Or, ces dernières années ont été marquées par un regain d'intérêt pour ce sujet, tant de la part des utilisateurs, qui réclament des équipements améliorés, que des constructeurs, qui sont en mesure d'offrir des systèmes de plus en plus performants. Par conséquent, les forces aériennes de plusieurs pays membres de l'OTAN s'approvisionnent en systèmes modernes et sophistiqués de planification de mission qui dépassent de loin les capacités de ceux jusqu'alors disponibles.

Ce changement s'explique essentiellement par la façon dont les technologies de l'information sont utilisées par les unités navigantes et les unités au sol des forces aériennes. Les avions militaires modernes sont pourvus de compartiments avioniques où les fonctions de navigation, commande de vol, télécommunications etc... sont conjuguées en un seul système cohérent qui possède au moins certaines caractéristiques de l'intelligence humaine.

Au sol, les renseignements concernant le terrain, les forces amies et ennemies, les objectifs etc... sont corrélés et acheminés par des réseaux jusqu'aux stations terriennes ou aux navires où ils sont exploités pour la planification.

Avant de lancer la mission le système avionique doit être initialisé en y entrant un grand volume de données fourni par le réseau au sol. C'est une des fonctions les plus importantes des systèmes modernes de planification des missions. Les données qui y sont introduites comprennent les données spécifiques à la mission, qui sont élaborées avec la participation des équipages. Ainsi, les activités de planification comportent un élément non négligeable d'étude et de simulation. Les nouveaux systèmes de planification de la mission font appel à de nouvelles techniques informatiques qui permettent de simplifier et d'accélérer la planification, l'actualisation, la simulation, le filtrage et le transfert des données.

Le groupe de travail commun 15 de l'AGARD a eu pour mandat d'étudier les systèmes de planification de la mission et de réfléchir à leurs évolutions possible. Ce mandat fait mention en particulier de la planification de la mission en vol, et de la simulation de la mission, dans le cadre d'un programme d'étude en deux phases. Ce rapport consultatif traite de la première phase des travaux uniquement.

Les membres du groupe de travail se sont réunis cinq fois pendant cette première phase. Le groupe a bénéficié également d'un certain nombre de présentations et de séances de démonstration organisées par les différents pays hôtes. Aussi, certains membres du groupe ont assisté à une réunion organisée par le NAFAG durant laquelle les problèmes de l'interopérabilité des systèmes de planification des missions ont été discutés. Nous tenons à exprimer notre gratitude pour les contributions apportées ainsi par de nombreuses personnes.

Les travaux de la deuxième phase porteront sur des domaines spécifiques ou des technologies en pleine évolution devraient permettre d'accroître considérablement les performances des systèmes. Ces aspects seront examinés dans un rapport ultérieur. Pendant cette deuxième phase les membres du groupe continueront à participer aux activités NAFAG concernant l'interopérabilité des systèmes de planification des missions.

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Contents

List of Acronyms

A-A	Air-to-Air
AAFMPS	Advanced Air Force Mission Planning System
ABDCCIS	Air Base Command and Control Information System
ACCS	Air Command and Control System
ACO	Airspace Coordination Order
ADRG	ARC Digitized Raster Graphics
AEW	Airborne Early Warning
AGARD	Advisory Group for Aerospace Research and Development
AGL	Above Ground Level
AI	Air Interdiction
AMP	Aerospace Medical Panel
AMPA	Advanced Mission Planning Aid
AMPS	Airborne Mission Planning System
A/N	Alphanumeric
AOI	Area of Interest
A-S	Air-to-Surface
ATC	Air Traffic Control
ATCCS	Army Tactical Command and Control System
ATF	Advanced Tactical Fighter
ATM	Air Task Message
ATO	Air Task Order
ATOC	Allied Tactical Operations Center
ATP	Allied Tactical Publication
ATPAL	Air Task Processing at Airbase Level
AVP	Avionics Panel
AWACS	Airborne Warning and Control System
BAI	Battlefield Air Interdiction
BFA	Battlefield Functional Area
BVR	Beyond Visual Range
C^3	Command, Control and Communications
C^3I	Command, Control, Communications and Intelligence
CAMPAL	Computer Aided Mission Planning at Airbase Level
CAP	Combat Air Patrol
CAS	Close Air Support
CD	Compact Disk
CINC	Commander-in-chief
COC	Combat Operations Center
COMM	Communications
CPS	Cockpit Procedure Simulator
CPU	Central Processor Unit
CVBG/BF	Aircraft Carrier Battle Group/Battle Force
3D	Dimension(al)
DBA	Data Base Administrator
DCA	Defensive Counter Air
DFAD	Digital Features Analysis Data
DITAM	Digital Terrain Analysis Model
DMA	Defense Mapping Agency
DTC	Data Transfer Cartridge
DTED	Digital Terrain Elevation Data
DTM	Data Transfer Module
ECM	Electronic Counter Measures
EDAM	Enemy Defense Analysis Models
E&E	Escape and Evasion
EO	Electro-optical
ETA	Expected Time of Arrival
EW	Electronic Warfare
FAC	Forward Air Controller
FAF	French Air Force
FARP	Forward Area Rearm/Refuel Point
FEBA	Forward Edge of the Battle Area
FEZ	Fighter Engagement Zone
FLIR	Forward Looking Infra-Red
FLOT	Forward Line of Own Troops
FWOC	Forward Wing Operations Center
GUI	Graphic User Interface
IAF	Italian Air Force
IFF	Identification Friend or Foe
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
INTAL	Intelligence at Airbase Level
INTEL	Intelligence
IP	Initial Point
IR	Infra-Red
ISMP	Integrated Strike Mission Planner
JINTACCS	Joint Interoperability of Tactical Command and Control Systems
JMEM	Joint Munitions Effectiveness Manual
JOG	Joint Operational Graphic
JTIDS	Joint Tactical Information Distribution System
LLTV	Low Light Television
MADAM	Munition and Delivery Analysis Models
MANPRINT	Manpower and Personnel Integration
MARPLES	Military Aircraft Route Planning Expert System
MB	Megabyte
MCS	Maneuver Control System
METAL	Meteo at Airbase Level
MEZ	Missile Engagement Zone
MIDS	Multifunction Information Distribution System
MISREP	Mission Report
MPS	Mission Planning System
MSS	Mission Support System
N/A	Not Applicable
NAFAG	NATO Air Force Armaments Group
NATO	North Atlantic Treaty Organization
NLR	National Aerospace Laboratory
NOTAMS	Notices to Airmen
OCA	Offensive Counter Air
OPORD	Operations Order
OPS	Operational
PC	Personal Computer
PIREPS	Pilot Reports
PPDB	Point Position Data Base
QRA	Quick Reaction Alert
RAF	Royal Air Force
RAM	Random Access Memory
RECCE	Reconnaissance
RF	Radio Frequency

RNLAF	Royal Netherlands Air Force
ROE	Rules of Engagement
ROM	Read Only Memory
SAM	Surface-to-air missile
SAR	Search and Rescue
SOC	Sector Operations Center
SORD	Statement of Requirements Document
TAF	Tactical Air Force
TAMPS	Tactical Aircraft Mission Planning System
TEAMS	Tactical EA-6B Mission Support
TLM	Tactical Line Map
TOT	Time-over-target
TRADOC	Training and Doctrine Command
TV	Television
UHF	Ultra High Frequency
USA	US Army
USAF	US Air Force
USN	US Navy
VFR	Visual Flight Rules
VHF	Very High Frequency
V/STOL	Vertical/Short Take off and Landing
WIMP	Window - Icon - Mouse Pointer
WVR	Within Visual Range

Chapter 1
Introduction

1.1. THE SCOPE OF THE WORKING GROUP.

AGARD Joint Working Group 15 was authorized in 1988 and commenced work in February 1989. Its members were nominated by the two AGARD Panels (Aerospace Medical and Avionics) that were responsible for establishing the Working Group and for its operation, together with two other Panels (Guidance & Control and Flight Mechanics) whose areas of technical interest were also relevant to the subject matter of the working group. The involvement of these nominees from four AGARD panels can be seen as an indication of the interest that has recently been generated by advancements in the field of mission planning.

The authorization of the Working Group was in recognition of the rapid development in the state-of-the-art in various pre-flight activities that can be grouped under the title "mission planning", that are aimed at maximizing the effectiveness of a military aircraft, including aircrew, in the subsequent mission. It was perceived, during the preparation of the terms of reference, that much commonality existed between the data used in pre-flight planning and that used during the mission, and the scope of the Working Group was defined to encompass planning and re-planning both pre-flight and in-flight. It also became apparent that the use of powerful airborne and ground-based data storage and data processing would allow aircrew to examine in detail some critical phases of the mission before actually flying them, leading to the concept of mission rehearsal as an extension of mission planning.

The Working Group was authorized to conduct its studies in two phases. Phase One was to cover an assessment of the overall concepts and the technical possibilities, together with the identification of critical technologies. The Working Group decided during Phase One that their studies should be oriented towards system tasks and features as well as towards technologies, and hence the conclusions of the Phase One studies included the listing of a variety of topics that were assessed to be worthy of further examination in Phase Two. This report has been produced at the conclusion of Phase One, and hence forms an interim report that is intended to provide a foundation for the follow-on activities of Phase Two. The topics identified as potential Phase Two study topics are listed in Chapter 8 of the report.

The planning and execution of a military aircraft mission, whether for practice in a peace-time situation or in times of tension or of war, implies that authority has been given and this authority will usually incorporate some constraints such as timings, routes, or rules of engagement. The planning and authorization may involve a number of levels within a chain of command, the degree of detail increasing progressively at the lower levels. The Working Group decided to concentrate its studies at the lowest levels, i.e. at the level of a squadron of aircraft operating from a single air base or from a single ship. Even at this level, the interaction between the planning and control of a single aircraft or a small group of aircraft and the control of a wider battle that may involve other assets such as sea and ground forces has a profound influence upon the low-level planning system requirements. In some types of mission the aircraft may be operating in an essentially autonomous role because they are unable or unwilling to communicate with other assets, while in other types of mission a high degree of collaboration and communication may be an essential feature. Thus, although the Working Group had originally intended to develop a generic model of a planning system that would encompass the whole range of possible aircraft types and types of operation, this proved to be an unproductive concept because of the dissimilarities in the control and in the flexibility allowed. Our studies thus concentrated upon four specific types of operation that could be specified and analyzed with some exactness, in the belief that these contained a sufficient range of different control and planning constraints to be reasonably representative of all current and future operations.

An essential element of the Phase One studies that are reported in this Interim Report has been a review of the methods currently used for mission planning by the Services in each of the participating nations. These methods range from very simple formulation of plans, using standard paper maps, to the use of current state-of-the-art computer based systems. Also reviewed were the systems that are currently being offered by manufacturers in several countries that incorporate further refinement and advancement over currently deployed systems; these we have called "emerging systems." Studies of the current and emerging systems provided an essential base for looking further ahead to systems that are likely to be developed in the middle to long term.

1.2 FORMAT OF THE INTERIM REPORT.

Following this introduction, Chapter 2 provides a background to the remainder of the report with outline descriptions of a mission planning system and of the chain of command in which it has to operate. It also describes the four missions that were chosen for study by the Working Group.

Chapter 3 defines nine characteristics of mission planning systems that the working group regarded as important in the subsequent assessments. Chapter 4 is devoted to a description of the methodology of mission planning for each of the four chosen missions, together with an evaluation of the procedures currently being used.

The large number of systems that have recently been and are currently being brought into use are covered in Appendix A and Chapter 5. Appendix A provides outline descriptions of a sample of them and Chapter 5 provides some comments on their performance in relation to the characteristics defined in Chapter 3. Using these systems as a baseline, the requirements for future systems that will give improved performance are outlined in Chapter 6; this is primarily concerned with ground based systems but some thought is given to the use of mission planning systems in the air.

Chapter 7 summarizes the results of the Phase One studies and Chapter 8 provides a list of some topics that are considered to be appropriate for further study in Phase Two.

Chapter 2
Background

2.1. DEFINITION OF MISSION PLANNING.

2.1.1. Functional Description.

In functional terms a ground based mission planning system is a system that allows all the available and pertinent information to be used to plan a mission to achieve certain objectives in an optimum or near-optimum way, and also allows data that describe the mission to be loaded into the aircraft. The earliest systems, and even some of those in use today, are no more than an assembly of printed data (maps, manuals, intelligence reports, etc.) together with a simple manually operated calculator that allows routes to be planned. These have evolved into the more modern equivalent that comprises a computer with various input/output channels and a range of peripherals such as displays.

Systems that conform to these descriptions generally have a shape similar to that shown in Figure 2-1. This diagram illustrates that a mission planning system is similar to many other data processing systems based around a small, powerful computer, and this is confirmed by the picture of a typical modern ground-based system shown in Figure 2-2. However, it has not generally been the practice to use general purpose workstations for mission planning purposes, and this is because mission planning requires some unusual hardware features as well as unique software. Principal amongst these is the need to store, process, and print highly detailed maps. Recent developments in commercial workstations have significantly improved their capabilities in these areas, and it appears probable that future mission planning systems may be implemented using workstation hardware and software that is commercially available.

The inputs to the system comprise data arriving via communication nets into which the system is coupled. Some of the data may be entered manually but it is anticipated that, increasingly, data will be in a form that can be directly input into the mission planning system computer. The principal output is the mission data to be loaded into the aircraft via cassettes or similar devices, or carried aboard by the aircrew in paper form. As mission planning systems become linked into networks, distributing mission data via the network will become an important requirement.

The interface with the operator is provided by various pointing devices, i.e., the mouse, trackball, digitizing puck, keyboard, and display. The keyboard is fairly typical and the display is now usually full color and of a higher resolution than provided in many workstations.

Because mission planning systems of the form shown in Figure 2-2, have the capability to accept and process data and to format it so that it can be loaded into an aircraft, this capability can be used for data not concerned with mission planning, e.g., data on IFF codes. Similarly the systems can be used for down loading and subsequently processing data at the end of a flight, (e.g., maintenance data on avionics and utility systems). Such usage has not been considered during the AGARD Working Group studies, but could be significant in the context of future NAFAG studies on interoperability.

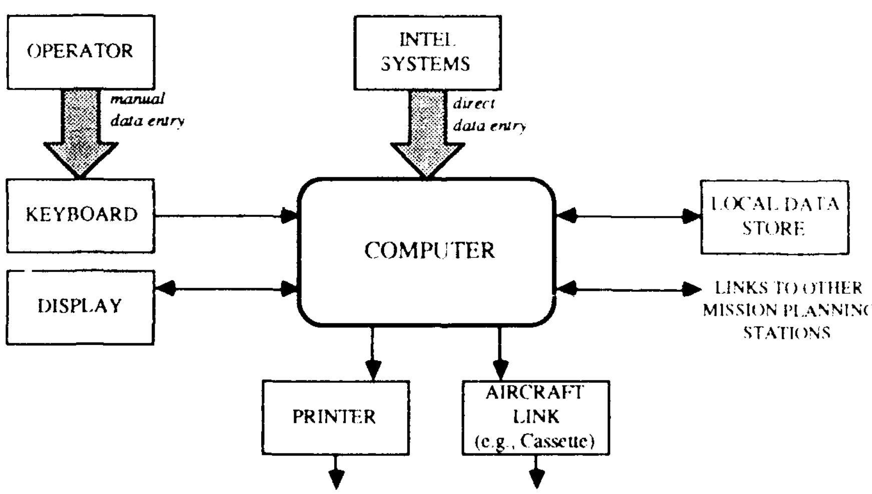

Figure 2-1. Schematic of a Typical Mission Planning System

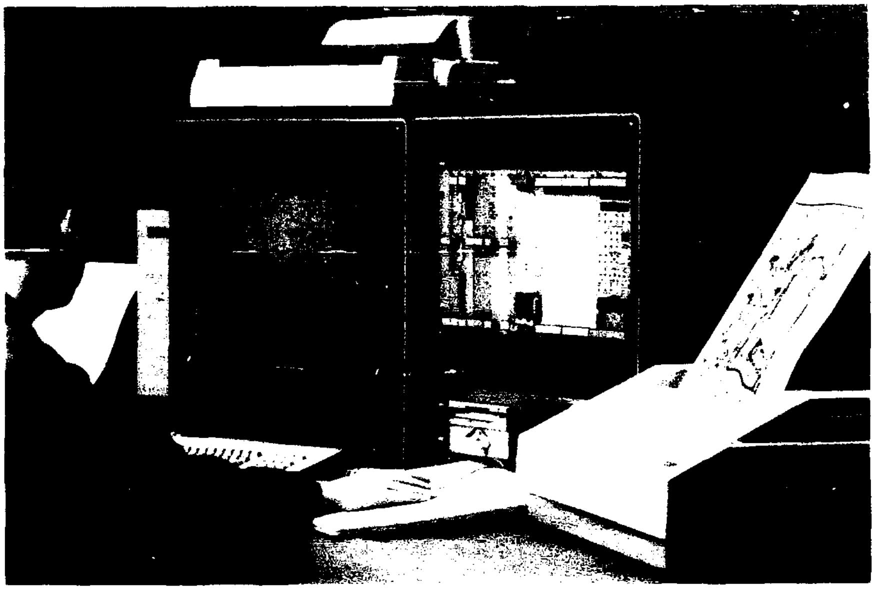

Figure 2-2. A Typical Mission Planning System

2.1.2. Key Objectives.

The rapid advances in the techniques of mission planning have to be seen in the context of parallel advances in other areas of information technology, notably in on-board avionics systems and in communications networks. Pre-flight mission planning can then be described as a process in which data is fused, filtered and compressed before being transferred into the on-board system for subsequent in flight use. With the increasing complexity of on-board systems, and particularly their incorporation of terrain based information, the need for much improved mission planning systems becomes clear and inevitable, otherwise the planning process will be slow and difficult to use, and the data supplied to the on-board avionics system would be inadequate.

The matrix in Table 2 1 lists eight key objectives for future pre-flight mission planning systems. Although all of these are estimated to be of real importance for most operational missions, the degree of importance does vary according to the mission. For each of the 4 missions studied by the Working Group, the objectives that are particularly important have been shown with an asterisk, some of the background justification for this assessment is provided in subsequent Chapters of this report.

The matrix shows that 4 objectives are regarded as of primary *importance for all the missions studied. The first 3 of these are:*

- Improved Attack Effectiveness
- Increased Survivability
- Improved Coordination

Of these, the first two are both aimed at devising a mission plan in which the aircraft has the best chance of achieving a satisfactory mission result. The third is an acknowledgement of the importance of optimizing the mission plans within a scenario of a complex array of collaborative force assets that must be properly coordinated to produce the best chance of mission success. The fourth objective of primary importance is interoperability, the need for which is clear on both a national and a NATO basis. It is unfortunate that interoperability becomes less easy to achieve as the complexity of mission planning systems (particularly their input/output characteristics) increases. It is clearly a topic that will require considerable attention and effort in the future, and it is addressed in several subsequent Chapters of this report.

2.2. CHAIN OF COMMAND IN MISSION PLANNING.

The difference in mission planning functions between wartime vs peacetime is decision authority, responsibility, type, and amount of asset control. After higher authority issues the strike planning order, probability of success for various mission options is evaluated by command level planning teams. The decision to execute a mission is context specific. For example, the strike order to demonstrate national resolve during peacetime at the National Command level; during wartime, however, the strike order originates no higher than the theater level. The mission planning function is different for levels within and between the various levels of the command hierarchy. To illustrate these differences, a Navy command hierarchy was selected that is composed of four levels: theater or commander-in-chief (CINC), battle force or battle group, strike warfare command or carrier wing commander, and route planner, targeteer, and weaponeer.

The theater or CINC command level require data on state of the deployed forces. This information includes the position of the

TABLE 2-1. Key Objectives for Pre-flight Mission Planning.

OBJECTIVE	MISSION			
	AIR DEFENSE	*CLOSE AIR SUPPORT* (Fixed-wing)	*CLOSE AIR SUPPORT* (Helicopter)	*AIR INTERDICTION*
Reduce Planning Time & Errors		*	*	
Reduce Planning Workload				*
Improve Attack Effectiveness	*	*	*	*
Increase Survivability	*	*	*	*
Improve Coordination	*	*	*	*
Increase Safety				*
Improve Resource Management			*	*
Interoperability	*	*	*	*

Note: "*" indicates that for the mission concerned there is a high priority associated with that objective

Battle Groups/Forces, land-bases and detached units. Types of detailed information required include extent of damage, number of aircraft available by type, and critical shortages of weapons, fuel, or other material. Other types of information include political climate, rules of engagement, weather conditions, and intelligence information.

The Battle Force/Battle Group command level requires information such as position, damage level, status of armament, principal sensors systems, critical shortages of surface ships, political restrictions, rules of engagement, and weather conditions. This information is critical for review of pre-planned missions, editing the strike plan, and effectiveness assessment of integrated military assets.

The strike planning command level requires more detailed but similar information as the Battle Group. Status information required includes readiness information on ships: position, course, endurance, sensor data, weapons available, damage levels, and time to repair, and on aircraft: availability, time to repair, complete weapons inventory strike, and weather, that is critical at this level.

Such data would likely come from sources higher in the chain of command. The major function of the strike planning board is to review and modify strike plans. The level of detail required includes parameters such as individual fuel states, weapons loads, routing to the target, intelligence data about the target area, and enemy defenses.

The final command level echelon is the route planner/weaponeer/targeteer. At this level, detailed information is needed on weather at the target and along the planned ingress and egress routes, and detailed information on the target area, layout of geography, (defenses, and assigned targets). Such required information would also include updates on defense strengths and positions, changing political conditions, and information on allied or neutral forces that would be involved. Plans based on this information are iterated until the team is comfortable with the probability of success.

Since the mission planning information is required at all command echelons within the Navy, it will be assumed that the same conditions will prevail for the NATO command structure. The question is, "at what echelon should the panel focus the study effort?" If the focus is on the lowest level (the squadron level) the problem is much more tractable than for higher levels in the command structure. However, the problems at the higher levels may be more relevant to design considerations for future mission planning systems. The fundamental objectives of this study are to address the state of technology for mission planning systems and to recommend directions for future research. To accomplish the objectives, this study panel focuses on mission planning systems that are employed at the squadron level, with consideration toward expanding the scope to include interoperability issues among command echelon structures.

2.3. MISSION DESCRIPTIONS.

As mentioned in Section 1.1, the Working Group found it necessary to restrict its studies to four different types of mission. These are best described in relation to NATO definitions of tactical air operations, that are themselves given in the NATO unclassified publication NATO Tactical Air Doctrine ATP 33 (11 March 1976).

2.3.1. NATO Definitions of Tactical Air Operations.

The four main types of tactical air operations addressed in this document are: offensive air, air defense, tactical reconnaissance, and combat air support. Some of these operations are further sub-divided by function.

- Offensive Air Operations if conducted in an air/sea environment are classified as anti surface operations, attack operations, and strike operations. If conducted in an air/ground environment, they are divided into Offensive Counter Air (OCA) operations, (Battlefield) Air Interdiction ((B) AI) operations, and Close Air Support (CAS) operations.
- Air Defense Operations if conducted in an air/sea environment are classified as anti-air (air defense) operations. If conducted in an air/ground environment

they are classified as Defensive Counter Air (DCA) (Air Defense).

- Tactical Reconnaissance Operations are conducted in both the air/sea and air/ground modes. They are classified as: reconnaissance operations, surveillance operations, and shadowing operations.

- Combat Air-Support Operations are classified as: Electronic Warfare (EW), Search and Rescue (SAR) operations, Special Air Operations, Airborne Control and Warning Operations, Mining Operations, and Aerial refuelling operations.

2.3.2. Representative Missions.

The four different types of operational mission that were selected for study were chosen to cover a range of different constraints and features, believed to be reasonably representative of most current and future operations. The examples were selected to illustrate:

- aspects that can be planned pre-flight and aspects that can only be planned in-flight,
- interoperability problems due to collaboration between NATO-countries, or due to one force intervening in the battle of another,
- operations by the air force, by the navy and by the army,
- fixed-wing operations and rotary-wing operations,
- time constraints,
- identification ("friend or foe") and
- communication problems.

Based on these criteria, the following four types of missions have been analyzed.

2.3.2.1. The Air Defense Mission.

Air Defense missions are designed to nullify or reduce the effectiveness of hostile air action. These missions are time critical because the initiative is with the enemy requiring that the majority of the planning be performed in-flight. Moreover, warning of air attack may originate from one country (or force) while the intercept is executed by another country (or force) thus illustrating problems that may occur in interoperability and communication. Air defense is geared to a potential air threat and consists of all measures designed to nullify or reduce the effectiveness of the attack aircraft or guided missiles in flight. Air defense involves active and passive defense measures. Active air defense is conducted to detect, identify, and destroy hostile airborne vehicles that threaten friendly forces and installations and has less variety in scenarios and is more time critical than passive air defense, which consists of measures that enhance survival to operate. In the context of this study, only active air defenses are of interest.

2.3.2.2. The Close-Air Support Mission.

Close-air support missions are designed to support friendly ground forces by attacking enemy forces in and around the FLOT. The typical close air support mission is a ground attack against either a fixed installation or against a column of troops/vehicles approaching the FLOT. The missions are usually initiated by the army. Aircraft frequently attack as a group of four, but other grouping such as pairs or larger groups are also used where appropriate. Pilots may fly a series of missions without getting out of their aircraft, returning to their base to refuel and rearm; in these circumstances the planning of the next mission is less sophisticated and must be carried out by the group leader individually.

2.3.2.3. The Attack Helicopter Mission.

Attack helicopter missions are designed to destroy massed enemy forces with aerial firepower, mobility, and shock effect. The attack helicopter mission encompasses a variety of activities including: rear area operations; coordinating indirect fire; suppressing enemy air-defense artillery; reinforcing ground maneuver forces; conducting joint air attack team operations with close air-support and field artillery assets; destroying enemy communication and logistics assets; disrupting and destroying enemy second echelon and follow on forces, protecting air assault forces; and destroying enemy helicopters.

2.3.2.4. The Air Interdiction Mission.

Air Interdiction missions are air operations conducted to destroy, neutralize, or delay the enemy's military potential before it can be brought to bear effectively against friendly forces; they are conducted at sufficient distances from friendly forces, that detailed integration of each air mission with the fire and movement of friendly forces is not required.

Targets for this type of mission include: groups of tanks, ammunition or fuel depots, as well as communications or C^3 nodes. Deep Air Interdiction is specifically aimed at defeating second echelon forces.

Air Interdiction missions are conducted by at least two aircraft flying at very low altitudes. Most of the time, such missions are integrated in a raid with specialized aircraft supporting the mission such as defense suppression, electronic warfare, and escort fighter aircraft.

Planning air interdiction missions takes much work, and can take as long the mission itself. However, in some cases deep air interdiction missions attacking second echelon divisions (follow on attack forces) may be executed using data supplied by reconnaissance aircraft obtained minutes before the attack.

Chapter 3
Assessment Methodology

3.1. ASSESSMENT FRAMEWORK.

The fundamental purpose of future mission planning systems will not vary significantly from the fundamental purpose of current mission planning systems. Future systems will capitalize on advances in technology, but must support planning for more advanced aircraft undertaking more complex missions. For these reasons, both current and future mission planning systems can be characterized within the same framework. This framework is comprised of 9 basic elements, and is described in the following Sections.

3.2. IMPORTANT CHARACTERISTICS.

The effectiveness of current mission planning methodologies and of emerging and future mission planning systems can be assessed relative to a set of performance characteristics that comprise the assessment framework. In this Section, we define 9 characteristics that are critical elements in determining the effectiveness and functionality of a mission planning system. These characteristics will then be used to evaluate the effectiveness of the current mission planning methods used in the four NATO tactical missions described in Section 2.3. The 9 characteristics are:

(1) Interoperability

(2) Database

(3) Communication

(4) Time

(5) Flexibility

(6) Ergonomics

(7) Deconfliction

(8) Mission Rehe-

(9) Growth Potenti.

These characteristics are defined below. The definitions given are derived, in part, from the following two documents.

(1) "Dictionary of Military and Associated Terms," Joint Chiefs of Staff, Washington, DC 20301, Dept of Defense, June 1979

(2) "NATO Tactical Air Doctrine," ATP-33(B).

3.2.1. Interoperability.

Interoperability is defined as (i) the ability of systems, units or forces to provide services to, and accept services from, other systems, units or forces, and to use the services so exchanged to enable them to operate effectively together, and (ii) the condition achieved among communications or electronics systems or items of communications-equipment when information or services can be exchanged directly and satisfactorily between them and/or their users.

Interoperability includes compatibility with command and control systems, intelligence information and sources, procedures, weapon systems, airborne and ground-based navigational aids, data transfer media, electronics, communications procedures and equipment for identifying friend from foe, and cross-servicing facilities.

3.2.2. Database.

The database for a mission planning system comprises all the data that can be made available for use during the mission planning process, and that can be entered into the mission planning system computer. It will principally comprise digital data, but some reconnaissance data in the form of images may also be used. A large part of the data is either unchanging or very slowly changing, so that update of this is rarely necessary and is in no way critical. However, some of the information (e.g., the position of both friendly and enemy assets) should be changed frequently to correspond to rapidly changing real world situations.

Database updates may be required for both ground-based and airborne mission planning systems. Database updating is the changing of information utilized within the mission planning system by replacement, addition, or subtraction of existing information with more current information. The accuracy of the information depends on the time lag between the occurrence of the change in the physical world and the occurrence of the change within the mission planning system's database. The size of an acceptable time-lag depends on the type of information and on how the information is to be used within the mission planning system. The mission planning system must account for both time skew, the difference of arrival time between two connected pieces of new information, and the utilization of an incorrect mix of old and new information (version skew).

Database updates can be performed in ground-based mission planning systems or in the mission planning avionics on-board the aircraft. In ground-based systems, the input may be made either by the operator or by direct link (see Figure 2-1.) In the airborne case, updates can be performed pre-flight, in-flight or post-flight, by either the pilot or automatically by means of a data link.

3.2.3. Communication.

Communication is a method or means of conveying information of any kind from one person or place to another. Telecommunication is any transmission, emission or reception of signs, signals, writing, images and sounds or information of any nature, by wire, radio, optical, or other electromagnetic systems.

If there are no tactical constraints, communications can be used between aircraft and between aircraft and controller (for intercept control, database updates, in-flight deconfliction). Communications may yield delays if they have to be encrypted. Transmissions may be corrupted by noise or other sources. The mission planning system must make assumptions about the validity of communications data when receiving it and must display measures of validity regarding the data to the mission planner on the ground or in the air.

3.2.4. Time.

Time is defined as the dimension of the physical universe that, at a given place, orders the sequence of events, and any designated instant in this sequence, such as the time of day. Aspects that are related to time may be on a relative or on an absolute time scale. Examples of relative time scales that are related to mission planning are speed of mission planning, frequency of database updates, response time between the inquiry to a system and its response, and readiness for use of a system. An absolute time is required for co-ordination and deconfliction with other friendly forces (or their weapons), notably a desired Time-Over-Target (TOT).

3.2.5. Flexibility.

Flexibility expresses the willingness to yield to the influence of others, and characterizes the ready capability for modification or change, by subsequent adaptability to a new situation. Flexibility of a mission planning system is important in that it supports the creative application of weaponry against targets. Flexibility of the mission planning system enhances survivability and lethality of the weapon system by allowing the human component of the weapon system to be utilized most effectively.

3.2.6. Ergonomics.

Ergonomics, or human factors, is the discipline that uses the understanding of human limitations and capabilities when designing mission planning systems. Ergonomics is an applied science that draws upon several disciplines, including psychology, physiology, anatomy, mathematics, engineering, and the physical sciences. Achieving an optimal fit of system requirements to operator's perceptual, cognitive, and performance capabilities of the mission planner is dependent on a complex set of factors dictated by the nature of design, the inclinations and bias of designers, and the availability of usable data resources. A mission planning system designed for international use must consider the characteristics of the human from a generic perspective, an individual perspective, as well as a cultural or national perspective. Examples of ergonomic design considerations include: how the mission planning system detects and displays what it determines to be incorrect entries by the mission planner and what resolution is required for visual displays utilized in mission rehearsal.

3.2.7. Deconfliction.

Deconfliction is the avoidance of situations where specific parameters of two or more friendly delivery vehicles are scheduled such that their proximity violates the established separation criteria for those parameters. Deconfliction is obtained by separation in parameters such as time, space, and electromagnetic frequency. Deconfliction is required within a force, between forces, and between services (e.g., army, navy, air force). Examples include:

- Offensive Counter Air. In large groups of attacking aircraft, conflicts may occur between aircraft and the fragmentation of their weapons.
- Close Air Support. The Air Force intervenes in (or operates close to) the army's battle and operates amidst friendly air defense fighters or by surface-to-air missiles.
- Air Defense. Attacking enemy aircraft can be intercepted by other friendly air defense fighters or by surface-to-air missiles.

The four examples in Section 2.3.2. illustrate deconfliction aspects that are also applicable to other types of missions (e.g., air interdiction, tactical reconnaissance, tactical air support, and combat support operations.)

3.2.8. Mission Rehearsal.

Mission rehearsal refers to some specific activities that may be performed (before the start of the mission) by the pilot and crew that serve to improve mission effectiveness. Such activities include previewing critical mission phases using visual, radar, and/or IR imagery, practicing critical mission activities (e.g., pop-up, weapons release) and real-time simulation of the mission using computer generated imagery.

3.2.9. Growth Potential.

Growth potential, within the context of this report, is the capability of a mission planning system to expand or increase performance or functionality in the characteristics described above. As an example, a single-user mission planning system that has the capability to increase the realism of its mission rehearsal ability by not excluding the capability of communicating with other single-user mission planning systems has growth potential. Another example is the ability of a mission planning system to add a new display device, such as a helmet display, that would enhance the ability to perform mission rehearsal.

Chapter 4
Current Mission Planning Procedures

4.1. AIR DEFENSE.

4.1.1. Mission Planning Methodology.

Air defense planning for an Air Base Defense or Aircraft Carrier Battle Group, Battle Force (CVBG/BF) is the responsibility of the respective commanders. Air defense requires a flexible control of resources that include surface-to-air missiles (SAMs), airborne early warning (AEW) aircraft, AWACS/E-2Cs, tankers, interceptors, and fighter aircraft. The resources are applied to the defense of air bases or carrier groups, as appropriate.

Air defense of the air base/battle group requires a plan to respond to the flexibility and speed of enemy forces to counter the enemy's effective air power. Speed is attained by early detection and warning of an attack, and flexibility is attained by having a set of air defense systems that cover a large geographical area and various altitude ranges.

The method employed to address these requirements involves the distribution of resources to defend zones around the air base or the battle group. The generic sequence of functions in air defense for both the air base and battle group are:

(1) early detection and warning of air attack, and determination of location, direction, size and possible intentions of the attacking force

(2) communication of attack details to active defense units by tasking of manned aircraft (interceptors/ AEW/AWACS/fighters), or by launching SAMs

(3) control of interceptors and/or SAMs by point defense command centers

(4) target acquisition and identification

(5) use of weapons

(6) simultaneous but separate offensive counter air operations

Early detection, warning, and determination of location, direction, size, and possible intentions of a hostile air attack force are essential to the successful provision of air defense. Traditionally, early warning of an air attack has been provided by ground-based systems. Conventional radar wave propagation is restricted to line-of-sight, however, mounting the radar in airborne platforms and spacecraft technology significantly increases the theoretical horizon. Early detection of hostile forces will remain a key challenge as developments in stealth technology proceed.

The air defense commander's task is to ensure that defense forces are effectively deployed to intercept the attack forces assets and to efficiently use interceptors, SAMs, guns, etc., for point defense. Key to effective defense is communicating, to the defense network, the intruding aircraft's position, type, and number, at a sufficient distance from point defenses to permit full use of the defense screen. Air defense depends upon pre-assignment of defense assets, interceptors, and SAM systems to pre-determined engagement coordination of communication among the defense assets and contingency planning if conditions degrade to the point where independent action is required by the defense systems.

The major concern of the sector controller (on the ground, in an AWACS, or E-2C) is to task different defense systems with targets that may consist of multiple elements, within a limited time span. If the sector controller decides to use interceptors, he has various options: aircraft with beyond visual range (BVR) capabilities; aircraft with multiple target engagement capability; or aircraft with within visual range (WVR) capabilities only. Aircraft may be in an already established Combat Air Patrol (CAP) or still on the ground and scrambled from a Quick Reaction Alert (QRA) depending on the defense context.

In intercept missions, detailed targeting can be performed by the flight-lead (within 30 seconds). Simultaneous, but separate, offensive counter-air operations by the enemy may intend to attack the interceptor's recovery bases; this may make the intercept force vulnerable if it returns during or immediately prior to the attack because their aircraft are exposed.

Planning Protocol. Initial planning is the responsibility of the Command with the delegated responsibility for air defense. Planning and tasking data concentrate on air space management information and combined Allied Tactical Operations Centers/Sector Operations Centers (ATOC/SOC) operations. Protocol concerns include: point of intercept; airspace coordination orders (ACOs); fighter engagement zones (FEZs); missile engagement zones (MEZs); forward line of own troops (FLOT); offensive missions that pass through the combat air patrols (CAPs); tanker tracks; center points of racetrack orbits ("bull's eyes"), also those of other CAPs; IFF switching; jamming procedures; and political boundaries. In addition, the tasker has to consider alternatives (what to do if the defenses fail? and what are the procedures and rules of engagement if communications are interrupted?).

As with any mission type, the time span between tasking and launch can be reduced by splitting the planning into a ground-based part and an airborne part. Planning may be performed by the tasking agency, by experts from wing or squadron, or by the pilots. The planning protocol involves ground-based or pre-mission planning and in-flight functions.

Regardless of the way in which a mission is executed, activities that can be performed pre-flight (and are not performed by the tasking center) are:

- decisions on weapon employment
- drawing up of rules of engagement (ROE: "identify or not?")
- mission altitude
- fuel calculations ("Joker fuel")
- lost procedures
- standard approach and recovery procedures
- optimization of engagement options and tactics,

- deconfliction (intra-flight, and airspace coordination relative to anti-air defenses)

CAPs use visual lookout and radar search to detect hostile aircraft. Consequently, additional pre-flight planning activities for CAPs are:

- expected direction of enemy attack
- radar search requirements
- mutual cover of the aircraft of the CAP
- the patterns that are flown within the formation
- the pattern that is flown by the defense force as a whole

Activities that have to be performed in-flight are:

- fuel calculations (before engagement)
- selection of pre-planned options
- target assignment (intra-flight, and relative to anti-air defenses)

The ratio between pre- and in-flight planning at the squadron level depends on how the mission is tasked: CAPs are established in a known area and may be pre-planned. On the other hand, missions that are scrambled from a QRA, have to be almost entirely planned in-flight (including some of the pre-flight activities listed above).

4.1.2. Evaluation of Current Procedures.

Interoperability. Air defense planning is a combined manual and automated process that is dependent upon the skills and experience of command staffs. Inter-communication among assets is essential for the execution of optimum screening patterns to prevent hostile actions. Assuming reliable communication equipment, interoperability among defense system assets is effective for routine operations. The problem emerges during hostile action when the enemy assault force deploys deceptions, e.g., ECM to disrupt communications. Such action severely reduces the overall effectiveness of the C^3I network. Coupling the effects of deception with the continuing requirement for command to control and manage multiple communication networks and data links, to maintain cognizance for detection, reporting and tracking of enemy targets imposes high workload and stress on the unaided operator, and it is possible that the expected C^3I requirements are moving beyond operator capability.

Database Update. Accurate presentation and inter-prediction of the latest available data are essential for speed and flexible response to hostile action. Improvements are currently required to upgrade the sophistication of display systems to improve situational awareness within the defense network. Additionally, digital data management techniques are required for real-time transmission and update to the database, (e.g., threats, meteorological conditions, position of friendlies, and transmission of the results of the defense system).

Communication. For non-conflict area defense, UHF/VHF radios and data links are used for the transmission of information relevant to the defense screen. The limitations of the current technology are related in Section 4.1.1 above.

Time. The enemy air force including missile and ECM systems will attempt to exploit its strengths, flexibility, and speed. The counter to speed is early detection of the attacking forces, and rapid planning and deployment of friendly forces.

Flexibility. The counter to the enemy threat is to have, in place, an air defense system that covers a large geographical area and various altitude ranges with sufficient weaponry to neutralize the enemy force.

Ergonomics. Air defense planning is currently largely performed manually. Preflight mission planning is restricted to collating up to date information on war procedures, safe lanes, etc. This must take the minimum amount of time when aircraft are on Quick Reaction Alert. In-flight mission planning is restricted to updating this information via the data link due to the rapidly changing situation. This situation places a high level of decision making on the aircrew, decisions that need to be made on the basis up to date information.

Deconfliction. Deconfliction is an integral part of the pre-mission planning process. Extensive practice of defense system routes reduces the importance of this issue.

Mission Rehearsal. Mission rehearsal is not currently performed for the air defense mission.

Growth Potential. A digitized database update capability, discussed in Section 5.2, is essential to a timely update of defense system tactics. This capability is central to improved interoperability for near real-time adjustments to protect point defense assets.

4.2. CLOSE-AIR SUPPORT.

4.2.1. Mission Planning Methodology.

Planning starts with an order to attack a particular target. There are two levels of the planning task. The first is where an order comes into a mission planning room; the cycle of this planning activity can take from one to twenty-four hours. The second is where the next attack takes place with the pilot still in the cockpit; the crude planning task in this situation can take as little as five minutes.

The most common mission planning equipment used for CAS are the ubiquitous maps, paper and pencils. Other more sophisticated equipment has either been introduced recently or is imminent. These are reviewed elsewhere in this report.

Ground-based Planning. The typical order provides the aircrew and support staff, with such information as the type of target (e.g. troops, stores, tanks), the type of attack (e.g. harass, destroy), grid references of primary and secondary targets, time on target (planned time and latest time), positions of friendly troops and appropriate communications frequencies, in flight call sign and frequency, number and type of aircraft, number and type of weapons to be used, positions and types of SAMs protecting each target. With this information the mission planning begins in earnest.

For a multi ship attack, the planning tasks are usually allocated in a pre-ordained manner between the crew members who will execute that attack. The main task typically starts on a 1:500,000 scale map. First the current FLOT, Fire Support Co-ordination line and IFF switch-on/switch-off lines are drawn. Then the set routes and turning points are drawn. These are normally changed every 24 hours.

Next the attack execution is planned. A 1:50,000 scale map is used for this task; this provides a detailed view of the terrain and other local features. The level of detail associated with this part of the planning task varies with the type of aircraft and the procedures used by a particular force. At the simplest level, attack planning is based upon an immediate interpretation of the map. At its most complex, it may include a 3-D preview of the target zone constructed from radar and/or map data. Once an appreciation of the local terrain has been gained, IPs are chosen and routes are plotted that include cross over patterns for each pair of aircraft. Typically a separation of 5 seconds is planned for each aircraft over flying the target. Collision avoidance during crossover is the responsibility of the following aircraft. Frequently a route is also plotted to an alternative or dump target, so that if an aircraft misses its opportunity to attack the prime target for some reason, the mission will not have been wasted. Finally routes from either the main or dump targets are planned to take the formation back to the day's set routes.

Airborne Planning. The sophistication of mission planning is effectively limited by the levels of technology available in todays cockpits. The set routes drawn on the 1:500,000 scale map will probably suffice for the next mission, when such a quick turnaround is expected. Planning in these circumstances will usually be done by the lead pilot using a 1:50,000 scale map resting on his lap. Consequently the planning activities as described above are done very crudely within a few minutes of receiving an order. The rest of the squadron is briefed over the radio and the new mission data is entered into each aircraft system, while the aircraft are being refueled and rearmed. It can take as little as 5 minutes for some squadrons to turn around and be ready for take off.

4.2.2. Evaluation of Current Procedures.

Interoperability. Certain features will be required if an effective level of interoperability is to be achieved for the CAS mission. The most significant will be the introduction of compatible command and control systems, that enable the timely dissemination of intelligence information and of effective IFF systems integrated with all friendly force equipment. In short, a well designed information distribution system must be a central feature of an interoperable mission planning system.

Database Update. Most current systems are not based upon a digital database, and so the question of update does not arise. However, as will be apparent from Chapter 5 (on emerging systems), such databases will be the norm in the future. It is important that each database should have the ability to be updated easily with the current information from elsewhere in the system, without imposing an onerous task load upon the relevant operator.

Communication. Communication is at the core of the planning task, and yet as a general rule, once airborne, any transmission during a CAS mission is undesirable from the point of view of stealth. This generates the requirement for a comprehensive on board planning capability, with the associated ability to transmit a complete new plan to all interested parties, with the absolute minimum of emission.

In the NATO scenario, problems are to be expected, arising from the variety of equipment being used by the different nations and also by the different forces within each nation. Even if this were to be overcome, the problem would remain of ensuring that the intended recipient of any message, has his equipment configured in such a way as to enable him to receive notification of a change to a particular plan.

Time. Planning a CAS mission can take from as much as 24 hours to as little as 5 minutes. The quicker the plan is constructed, the less likely it is to be effective, in that with current technology, the available time will reduce the number of parameters that can be taken into consideration. More comprehensive mission planning tools should redress this by evaluating a large range of alternatives and a large number of relevant parameters in a very short time. We would thus hope to be able to produce sophisticated plans in a very short time; a few minutes on the ground, a few seconds in the air.

Flexibility. Flexibility in the context of the CAS mission refers to the ability to adapt to last minute changes. This might be to new information received whilst the mission is actually being planned, or to information received while in the air. Currently the amount of flexibility is curtailed by the limited amount of data available once airborne and the limited amount of time available to dedicate to the re-planning functional. Typically, the extent of planning is limited in this situation to a quick look at the map and a snapshot decision by the pilot, based upon an amalgam of his current appreciation of the situation and his past experience.

Another common cause of inflexibility arises when a flight has had to deviate from its planned route. The group then typically follows the leader, and so from that point the mission starts to become inflexible. It would thus appear that current equipment does not enable groups of aircraft to operate as flexibly as would be desirable in a dense hostile environment. Mission planning systems should be developed specifically to meet this requirement.

Ergonomics. The planning of close-air support missions is still predominantly carried out using maps, pencils, and stop-watches. Routes are planned as a series of waypoints to an initial point from where the attack is planned. This would take advantage of terrain masking and aircraft target runs from different directions to surprise the enemy; and precise timing to reduce the risk of fratricide. Missions may need to be planned in 2-3 minutes allowing minimal preflight planning or may need to be re-planned in flight.

Current mission planning is hampered by the lack of integration of the data sources and the separation of the planning task and the entry of the data into the aircraft system. To speed up the process, the aircraft system should be capable of being updated in flight and/or of allowing quick planning of missions on the ground with the crew remaining in the aircraft, to increase sortie rate.

Deconfliction. Deconfliction is planned at an operational level, above that of the squadron, and is coordinated by reference to times on and off the routes as set for that day of the battle. In the region of the FLOT, IFF equipment is used to ensure the deconfliction of the airborne and ground based forces.

Mission Rehearsal. At present, mission rehearsal is performed by studying the mission plan using paper maps and through crew briefings.

Growth Potential. In the short term, aircraft with data buses such as 1553B, potentially have the capability to extend their mission planning capabilities (albeit that extra processing may be required). However, the financial and contractual hurdles that would have to be overcome in order to introduce such facilities, are to say the least, considerable. Nonetheless, an

expansion of the capabilities in this area can be expected, as updates to current CAS aircraft and as a central feature in the future.

Current ground based planning systems, other than those introduced quite recently, would seem to offer little in the way of growth potential, and we might expect them to be phased out and replaced by more up to date systems. Of those introduced recently, such as TAMPS, and those that are imminent, such as AMPA, a growth potential to incorporate new features at a later date must be an essential requirement.

4.3. ATTACK HELICOPTER.

4.3.1. Mission Planning Methodology.

The attack helicopter mission planning methodology, as it is accomplished today, is a manual, labor intensive, and time consuming procedure. The overall planning for the mission is primarily done at the Aviation Battalion based on the Operations Order (OPORD) which is developed and received from higher echelons. The OPORD is analyzed and decomposed to a level that addresses each helicopter company within the Battalion, and then forwarded to the attack company for refinement. The attack company refines and tailors the Battalion plan in accordance with its specific capabilities and last minute situation changes.

The OPORD consists of descriptions of the current situation in terms of the enemy, friendly forces, and weather status; mission task, in a clear, concise statement of the task at hand (who, what, when, and as appropriate, why and where); execution plan, to include the plan of all supporting assets; service support, including, Forward Area Rearm/Refuel Point (FARP) sites, munitions, logistics, and health services; and command signal, including communications, navigational, IFF, code requirements, command data, and time synchronization.

The attack helicopter company commander is responsible for planning the mission once the OPORD is received. He is assisted by a planning cell which consists of designated personnel within the company. The planning process is divided into several phases: mission analysis, concept of operation, logistics, and command signal.

The company commander provides guidance to the planning cell which is responsible for accomplishing intelligence analysis, route planning, and semi-mission independent planning functions. The intelligence analysis consists of updating the current enemy threat environment, the friendly air defense artillery plan, their present locations and projected course of action as dictated by known enemy tactics. The current Intell picture is then annotated on a tactical chart/map (typically a 1:250,000 Joint Operational Graphic [JOG] map and/or 1:50,000 Tactical Line Map [TLM] of the operational area of interest [AOI]). The output of the Intell analysis feeds the route planning operation.

The routes (single and multiple aircraft) are selected in accordance with the mission objective requirements. Routes are typically selected to avoid enemy threats in terms of detectability and lethality along with consideration of readily recognizable terrain features to be used for navigational reference/check points. The selected routes are then examined by the personnel of the planning cell who are responsible for the semi-mission dependent planning functions.

The semi-mission independent planning encompasses monitoring the weather conditions in the AOI during the mission performance period, the communications needs, the weaponization of the aircraft in accordance with the mission objective, performing the weight and balance for the aircraft, and finally calculating the performance characteristics for the aircraft based on the airframe capabilities. In other words, determining if the aircraft can accomplish the planned mission over the AOI terrain. After it is determined that the aircraft can perform the mission, the performance characteristics (weight and balance, fuel required, etc.) are returned to the route planners and the necessary kneeboard cards are generated. The semi-mission independent planners also generate kneeboard cards for the communications and weather information required in the cockpit. The communications requirements are passed along to those responsible for the command and signal portion of the planning process. The command sand signal planners develop the kneeboard cards delineating the communications combat net radio assignments along with authentication codes, unit names, and sub-unit individual addresses.

The output from the Intel analysis and the route generation are consolidated with the original mission requirements and a concept of operation is developed. This encompasses examining the scheme of maneuver for both the aviation assets and the ground forces being supported by the aviation mission, the fire support requirements and available fire supports assets, and accounting for sub-unit tasking orders in support of the overall mission plan. The concept of operation is then annotated as an overlay to those tactical maps of the AOI. This information is also passed to those responsible for generating the coordination instructions.

The coordinating instructions take into account the required logistical support necessary to accomplish the mission. Based on the concept of operation, the mission objective, and the planned ingress and egress, the refuel and rearmament requirements are determined along with the optimal locations and time-on-site. Coordination requirements with other units are determined and the pertinent information is either annotated as an overlay to the tactical map of the AOI or the appropriate kneeboard cards are generated.

The overall output of the mission planning cell is all the pertinent data, forms, and maps needed to perform the assigned mission for each individual aircraft within the attack helicopter company.

4.3.2. Evaluation of Current Procedures.

Interoperability. The current attack helicopter mission planning procedure, at the company level, is done manually by the company commander and assigned personnel. The plan is based wholly on the OPORD received from Battalion and whatever locally developed information is available prior to the mission. The attack company has limited communications assets and interfaces to other battlefield assets which could be used for coordination. Therefore, company level interoperability/coordination with other battlefield assets is done primarily at Battalion. However, where limited coordination, situation update, and command and control are absolutely required it is accomplished either over voice radio where possible, through written communications via messengers, or through face to face meetings. The Battalion level mission planning assets have more communications capabilities available but still are limited in access to other battlefield areas. Here again dependency on voice radio, written message traffic, and face to face n...

prevalent. However, future developments in automated systems will enhance both the Battalion and Company interoperability.

Database Update. Since the attack helicopter mission planning process is not automated there is no electronically maintainable database. The data base used for planning is in the form of tactical overlays obtained as part of the mission OPORD. These overlays, or annexes, detail the necessary information from the other battlefield areas such as Fire Support, Air Defense, etc. Database updates therefore consist of annotating the various tactical overlays as new information becomes available.

Communication. Current communications are limited, since the organic communications assets of the attack helicopter company are generally restricted to combat net radios. These are in the VHF/UHF frequency spectrum and are inherently line of sight limited.

Time. Time is always a critical factor in mission planning. It can take as much as three hours of planning for every hour of actual mission flight time. Under the typical pressures of the heat of combat, the time factor becomes crucial, and impacts the quality of the plan and the ability to successfully complete the mission.

Flexibility. Flexibility in the attack helicopter mission planning process is extremely limited. The OPORD is generally sufficiently detailed at the company level to preclude any significant deviations. The only flexibility exists in the objective area for planning attack and alternate positions. This is primarily due to the limited communications capabilities at the lower echelons.

Ergonomics. Attack helicopter missions are planned using maps, tactical overlays, pencils, stop-watches, and mission cards, which contain basic mission data. The method is simple, robust and soldier proof. The perception of these features needs to be retained in the development of future automated mission planning systems to provide the bridge from the current manual process to the machine aided type planning. This is essential in order to gain user acceptance and confidence in the new automated system.

Deconfliction. Deconfliction is currently done manually. In the rear areas deconfliction is accomplished through Air Traffic Control (ATC) standard procedures and in the forward areas it is left up to the planners by picking the proper ingress and egress routes and the rigorous execution and adherence to the plan.

Mission Rehearsal. There currently is no mission rehearsal capability other than reviewing the available maps, photographic data and flight plans prior to the mission. A mission rehearsal function is necessary.

Growth Potential. The current process, being totally manually oriented, has very little growth potential. Future growth can only be achieved by replacing the present system with new computer-based systems.

4.4. AIR INTERDICTION.

4.4.1. Mission Planning Methodology.

The mission planning process at the squadron level mainly involves the crew of the lead aircraft; however, the rest of the formation does participate. The planning process begins upon the receipt of a mission order that includes a description of the target, what should be done to the target (e.g., destroy or neutralize), and when the target should be attacked. The tactical situation is also described; it includes the FLOT, transit roads and locations, and known surface-to-air missile sites in the battle area.

As a preliminary, the pilot estimates the feasibility conditions of the mission (e.g., speed, need for external tanks, in-flight refueling) on a 1:500,0000 scale map. When the gross characteristics of the mission have been determined, detailed planning begins.

First the target is carefully examined on a 1:50,000 map in order to determine the attack phase and the escape maneuver. The target's physical characteristics are analyzed and weapons are selected (if they are not already prescribed in the attack order). Next the weapons delivery sequence is determined as well as the attack axis and spacing for the different aircraft of the formation. These items are selected according to target location, terrain, weather, and defenses in the target area. The initial point is then selected and the rejoining procedures and escape maneuvers are planned. In most cases these steps are iterated until a satisfactory mission plan emerges.

The next step in the planning process is to plan the ingress and egress routes. This step requires waypoints to be selected between the starting base and the initial point and between the rejoin point and the landing base. Waypoint selection is determined by terrain, the tactical situation, and fuel and time constraints. The knowledge of the pilot about his own abilities is also taken into account. For a crew of two or more, this phase of planning is performed by the navigator. Once the waypoints have been selected fuel consumption and the mission time-line are computed. The times over the FLOT are communicated to troops in the battle area for fire coordination. The entire process is iterated to optimize the mission plan and to perform error checking.

During the iteration phase of planning, if time permits, alternative plans are investigated and secondary targets are analyzed. The final step is to prepare for the mission; maps are prepared, IFF procedures and COMM frequencies are obtained. This information is then loaded into the aircraft's on-board computer.

4.4.2. Evaluation of Current Procedures.

The planning process is a computationally intensive process that is heavily influenced by pilot experience. Current systems address the computational aspects of planning air interdiction missions (e.g., computing fuel and mission time lines) but do not address the issues of data collection and pilot experience. Gathering the information required to plan the mission is a particular problem. Much time is lost folding maps and searching for information that sometimes does not exist. However, the mission planners do favor some manual work and reflection because it allows them to become more familiar with the details of the mission.

Interoperability. For automated planning systems, interoperability is very limited because almost every class of aircraft within NATO has its own mission planning system that cannot interact with other systems. This limitation does not exist when missions are planned using paper maps and pencils.

Database Update. Facilities to update databases on the ground are quite extensive, but there is currently no mechanism for providing database updates to the aircraft.

Communication. Communications are very limited; most of the time radio silence is required so almost nothing is planned about communications.

Time. The time required to plan an air interdiction mission ranges from about 0.5 to 2 hours.

Flexibility. The flexibility of the current mission planning process is very limited because time of arrival at the target is critical and therefore there is little flexibility to modify the mission waypoints. However, pilots are able to make minor deviations to the mission plan to avoid SAM sites or to avoid arriving at the target too early. More significant deviations are not currently performed because they impose too great a work load on the crew and because they make it difficult for multiple aircraft to maintain formation.

Ergonomics. First generation mission planning systems are used in some aircraft types in producing air interdiction mission plans. But these generally suffer from a poor user interface that discourages the user and increases the likelihood of user errors. Air interdiction missions can take many hours to plan but in most cases time is not critical. Planning is performed using photographs, FLIR or radar pictures of the waypoints and targets that allows the mission to be rehearsed. In-flight circumstances are planned for, such as attacks by enemy aircraft and switching to secondary targets, minimizing the need for in-flight planning. Once the mission begins, the plan is strictly adhered to, particularly at night or in poor weather.

Deconfliction. Deconfliction is currently performed manually by the pilot. Deconfliction in the target area is achieved by rigorous adherence to the plan. Pilots rely on IFF and flight altitude for deconfliction in and around the FLOT.

Mission Rehearsal. Currently, mission rehearsal is not supported by electronic aids; at this time it consists only of a mission leader briefing other mission crews or of a single crew member studying his mission folder or being briefed by intelligence officers about threat and target characteristics.

Growth Potential. The growth potential of current planning procedures and systems is limited and it is expected they will soon be replaced with newer and more capable systems.

Chapter 5
Emerging Mission Planning Systems

In the past decade, the tremendous growth in computer technology has made it possible to automate many of the mission planning functions that in past years were performed manually. Many automated mission planning systems are currently being developed that offer the potential for mission planning to be done faster, more effectively, and with reduced errors. In Appendix A and in this chapter, we review the capabilities of emerging automated mission planning systems. In Appendix A we give a description of nine mission planning systems that were selected as representative of the types of systems under development and review these systems in terms of their applications, implementation and capabilities. During the review, the similarities and differences of the systems are discussed. In this chapter we assess the systems using the framework described in Chapter 3.

5.1. INTEROPERABILITY.

Interoperability of mission planning systems is desirable in two respects:

(a) In terms of the ability of such systems to communicate with a range of other component elements in an overall C^3I network.

(b) In terms of their ability to interface with a range of aircraft having different characteristics and different hardware and software interfaces.

In both the above respects there are three types of interoperability which need to be considered, electronic, physical, and ergonomic. Electronic interoperability means that the emerging mission planning systems must be able to interface to various inter- and intra-service, and international voice and data networks. This implies that either common protocols (standards) must exist or be implemented or that sophisticated and complex protocol interrupters must be developed. There are currently communications standards such as JINTACCS (Joint Interoperability of Tactical Command and Control Systems) which can be exploited immediately for the exchange of information. JINTACCS, although a US managed asset, has been extended to the international community through NATO agreements and therefore contains a significant amount of defined message forms which are relevant to the needs of mission planning in terms of gathering pertinent data from the various battlefield areas. In addition to the protocol interoperability, there must be some common communications media available at the planning sites in order to obtain the necessary planning data. This translates into common communications equipment such as radios and frequency allocations, facsimile, and possibly a common language, etc.

Physical interoperability implies a multitude of common characteristics which must be satisfied. In terms of mission planning this relates to common planning hardware, databases, maps, etc., However, paramount, is how a variety of different systems interface with one another and how the ultimate output from the mission planner interfaces with the aircraft and how the variety of different aircraft can utilize the different mission planning systems which will populate the future battlefield. The standardization of a common Data Transfer Cartridge (DTC) is required, however because of the diverse aircraft mission and physical differences within the international community this is not likely to occur. Therefore, emerging mission planning systems must have the ability to readily accept physically different DTCs along with the proper data formatting and electrical interface requirements for each of the compatible DTCs.

Ergonomically, emerging mission planning systems must have an operator interface which is somewhat transparent to the operator. This means that any pilot/planner can sit down at any planning system, with a minimum of familiarization, and perform the basic planning functions, i.e. route generation, associated with his own planning system. This approach requires a standardization of menus, presentation formats, symbology, and to some extent a mission planning language. One approach could be to implement a Graphical User Interface (GUI) running in a Windows environment. The GUI is dependent on icons to depict functions and could bridge the language barrier impediment associated with the international community.

Some emerging systems have limited capability in these three respects, e.g., the U.S. Navy's TAMPS system described in A.1.8 that operates within a U.S. Navy command and control network and is designed to plan missions for several USN aircraft. Other similar systems are listed in Table A-1. But it may also be seen from Table A-1 that there is currently no interoperability between the services or between the NATO countries, and this could seriously degrade the ability of the NATO forces to cooperate as an effective pan NATO force.

5.2. DATABASE.

The data that is to be used by a pre-flight mission planning system takes a variety of forms. It can be characterized into three main types: data about geographic features and weather; data about friendly assets that include both physical data and tactical plans for their use; and data about the enemy's assets. Much of this data does not change rapidly and can be held at air bases in a library or archive form. But some data, such as the location of friendly or enemy assets, is likely to change rapidly and hence mission planning systems are generally coupled to a communications net from which update information can be obtained. The types of data likely to be used in future systems are listed in Table 5-1.

5.2.1. Geographic and Meteorological Data.

Terrain data has historically been available in map form, typically at scales of 1:50,000 or greater. This is being superseded by digital data that, in some areas, provides resolution approximately equivalent to a 50,000 scale map, that is sufficient for most planning purposes. However, it must often be supplemented by more accurate altitude data in those areas where very low flying is planned, e.g., in the target area.

Cultural features are also shown on maps; and include railways, roads, towns etc. Most of these are being included on digital data bases and most will require to be updated fairly

infrequently. It should be noted, however, that some features that are critical to aircraft operation and to mission planning may not be reliably represented on data bases; examples of these are tall structures such as chimneys, and power cables and masts. Both terrain and cultural data may also exist in the form of images obtained from reconnaissance aircraft and satellites. This can provide much higher resolution than the digital data referred to above, which can be particularly useful in generating visual scenes, for example of potential target areas. Current systems have only a limited capability for fusing together the information available in digital and image form; as listed in 6.1.2, future systems may be expected to be much improved in this respect.

Meteorological data has always been of high importance to mission planning. It will be most useful in the form of predictions, and hence cannot be derived directly from sensors but requires additional intelligent judgement to be applied in merging the weather data that will be available from a range of sources. A network exists that is dedicated to the supply of weather data to NATO operational units; much of the data is currently handled manually and improved capabilities to manipulate, display and apply this data are currently being implemented.

5.2.2. Data on Friendly Assets.

Much of the data listed in Table 5-1 is in the form of numerical information on the physical assets that will be deployed during the mission, especially the characteristics of the aircraft platforms, their weapons, and their avionics systems. For the most part, these characteristics will require infrequent updating, although the characteristics of individual aircraft (e.g. measured engine performance) may need to be updated at a higher rate. Information on numbers of aircraft and weapons, their status and availability is also important in planning and will require frequent updating in a wartime scenario.

For land-based aircraft the airfields that can be used are well established, but some types of helicopter and fixed wing aircraft may operate from remote sites whose characteristics and location must be known. For aircraft and helicopters based on ships the ship position (and anticipated position during the duration of the mission) must be available to the planning system.

The status of the aircrew is an important parameter in mission planning, although characterization of individual crews is not easily quantifiable and it is unlikely that this can be input to a mission planning system except as a judgement made by human operators.

Mission planning systems are normally used as a method for loading data into an aircraft before a mission begins, some data may be required for this purpose that is not necessary in a strict planning sense. Examples in this category are: frequencies to be used for radio communication during the mission, IFF codings, and weapon fusing and aiming data.

TABLE 5-1. Data used in mission planning systems.

	Required for Pre-Flight Planning	Outputs from MPS to the Aircraft	Additional Data Required for In-Flight MPS
Geographical & Meteorological			
Terrain	•	•	
Cultural Features	•	•	
Image Data (e.g., Photographic)	•		
Weather Data	•	•	Update
Data on Friendly Assets			
Airfields/Aircraft Carriers	•	•	
Aircraft			
Type Data	•	•	
Individual Aircraft Data	•	•	
Vulnerability Model	•		•
Aircraft Status	•		
Crew Status	•		
Weapons Characteristics	•	•	
IFF & Comm	•	•	
Other Assets	•	•	Update
Data on Missions and Tactics			
Pre-planned Missions	•		
Corridors/Routes/IPs	•	•	
Tactics and Rules of Engagement	•		•
Data on Enemy Assets			
Threat Data (Aircraft)	•		
Threat Data (Weapons)	•		
Threat Locations	•	•	Update
Tactics	•		•
Target Locations	•	•	Update

The extent to which knowledge of other friendly assets is required depends upon the type of mission; other aircraft may be integrated into the plan, e.g. for in-flight refueling. Ground assets such as observers or target locators may need to be included. For the most part, these assets will be mobile so that data concerning them will change with time. Up-to-date information is fed into the mission planning system with manual inputs from liaison staff.

5.2.3. Data on Missions and Tactics.

Many of the mission planning tasks undertaken in wartime will correspond closely to mission planning tasks required during peacetime training. Much of the information generated during such training can therefore be drawn upon provided it is available in a usable form. A database of pre-planned missions is frequently maintained in the form of both complete and partial missions. This facility is particularly useful in the attack phase on pre-planned targets, although transit routes are likely to be highly dependent on the battle situation.

For those missions and mission segments where pre-planned data is inappropriate, the tactics and rules developed in training and rehearsal must be used by the planner. These are currently input manually into the planning system by the operator, but in some current systems a degree of automation is already provided, particularly in the deconfliction of aircraft involved in a multiple aircraft operation.

5.2.4. Data on Enemy Assets.

As with the data on friendly assets described above, much of the data on enemy assets describes the performance of aircraft and weapons type, e.g. the characteristics of SAM systems that may be required for lethality calculations. For fixed SAM sites such data requires infrequent updating. The positions and other data on major fixed facilities such as airfields is also largely static.

Other data on enemy assets, e.g. the location and magnitude of moving assets, together with information on perceived tactics and strategy, is available to intelligence staff from a variety of sources and at uncertain intervals, e.g. following a reconnaissance mission. It is necessary for the mission planner to accept data from the intelligence staff in a suitable form, after it has been filtered and collated. It is conceivable that the mission planning system could itself be used for this filtering and collation process.

The need for rapid updating of information on the enemy's mobile assets implies that in some cases the communication and filtering processes may take so long that the information's validity may be seriously degraded. In such cases it may be appropriate to consider direct communication links between mission planning systems and reconnaissance sources such as satellites.

5.3. COMMUNICATION.

Communications, or the transfer of information from one source to another, is a component of current mission planning systems. The extent to which communications are functionally supported by current mission planning systems is not consistent across systems. Communication requirements for future mission planning systems will remain an important component but will not remain constant in relation to current mission planning systems. The communication requirements for future mission planning systems will increase relative to the capabilities of current systems. These increased requirements will include the amount, quality, security, and number of different types of information. The requirements are driven by several sources, particularly the integration of the mission planning system into C^3 systems. The mission planning system of the future will communicate directly with C^3 networks in real time. This rapid exchange of information between planners and controllers supports the effectiveness of both systems as well as increasing capability relative to conventional mission planning systems.

5.4. TIME.

Time problems in emerging systems are of various types.

(1) <u>Mission Planning Duration.</u> The average value (35 minutes) is not far from acceptable values for air interdiction missions, but would be quite inadmissible for other kinds of missions.

(2) <u>Data Base Update.</u> At present, tactical information (friendly forces, intelligence) is manually updated so its average age can reach several hours.

(3) <u>Mission Timing.</u> Except for AMPS, CAMPAL, and CINNA 3, that can handle multiple aircraft formations, the considered emerging systems are for single aircraft; and every timing problem detected at the single aircraft planning level must be solved at the upper level, which costs planning time.

5.5. FLEXIBILITY.

In Section 3.2.5, flexibility has been defined as "expressing the willingness to yield to the influence of others and characterizing the ready capability for modification or change by subsequent adaptability to a new situation". Key to flexibility is the development of an infrastructure of interactive hardware and software tailored to the unique mission planning functional requirements. Important functional requirements of emerging systems include: improved design of human-computer interaction, inclusion of automated subsystems for analysis and calculation, and the capability to flexibly create and display information.

Particular emphasis is being placed on user friendly design features that result in easier control of the direction and pace of the planning process without extensive training in computer operation or data processing. Such design features are fundamental to rapid, accurate, and varied use of the mission planning system's inherent capabilities.

Critical to the speed and accuracy of the planning process is the development and automation of algorithms for database analysis and calculation. Algorithms that are networked among real-time, large and accurate databases for navigation, tactical intelligence, and aircraft and weapons data permit the planner to concentrate on the practical factors that are integral to mission planning.

Display generation, modification, and fidelity are being emphasized in emerging systems. The combination of capabilities in color graphics, 3-D perspective, real-time database update, multiple database integration, and knowledge-based systems are being integrated to provide high fidelity, pre-mission planning with potential for in-flight management.

5.6. ERGONOMICS.

The second generation of mission planning systems now being developed are far more ambitious in their scope and size. This increases the importance of ensuring that the ergonomics of the system are considered at the initial stage of the design process and that the user interface fully supports the user.

Much effort is being placed in providing an optimum user interface that is easy to use, particularly for users untrained in computing techniques. Interfaces using window techniques and menu or question/answer based dialogues predominate. Familiarity for the users is enhanced by the use of familiar symbology and planning techniques. A well designed user interface should help in reducing the high preflight workload and time taken to integrate the large amount of information to the user on the database.

The design of the output of the mission planning process also needs careful ergonomic consideration. Many of the emerging systems produce hardcopy mission information in the form of a mission card or folder. Information fed directly into the aircraft's systems requires careful design as to how, when, and what information is presented to the aircrew and how it is integrated with existing systems, e.g., AMPA is to display route, threat, and comm data on a digital moving map display.

The development and deployment of data link systems in aircraft will enable in-flight plan updating to take place. The effect on pilot work load will require investigation and subsequently will influence system design.

Systems employing AI techniques such as MARPLES, should have a high level of system logic and transparency. Aircrews will not accept a mission that has been planned for them, if they do not understand the reasoning for each decision.

Generally all the systems being developed aim to speed up the initial information integration tasks of the mission planning process while automating the complex calculation stages. AI techniques may have an important application in this area.

Finally, emerging planning systems may need to conform to programs such as MANPRINT, that will require ergonomics to be considered at all stages of the system design process.

5.7. DECONFLICTION.

In Section 3.2.7 deconfliction has been defined as "the avoidance of situations where specific parameters of two or more friendly aircraft are scheduled, such that their proximity violates the established separation criteria for those parameters". Potential conflicts can arise either from unacceptably close distances between aircraft and weapon fragmentation envelopes, by inadequate spatial separation between two aircraft during ingress, attack, or egress, or by uncoordinated use of communication frequencies or jammers. In general, deconfliction is required: within a force, between forces, and between services (army, navy, air force).

None of the emerging automated mission planning systems that were reviewed performs deconfliction between forces or between services. This function is currently performed by higher command and control echelons. Automation of these types of deconfliction is a requirement for future mission planning systems (see Section 6.1.7).

At present, deconfliction between forces and between services is covered by secondary conditions as stated in the Air Task Message (ATM); examples are: time constraints like time-on-target, special routings (ACOs), and communication frequency settings. Because this data is an input to present systems, these types of deconfliction are not very flexible; the detour through higher command and control echelons makes deconfliction very time-consuming. If at all, the present emerging systems only deconflict intra-force between aircraft or between aircraft and the envelopes of their weapons. This implies that there should be some communication between the planning process for each aircraft in the target area. Implemented aspects for intra-force deconfliction depend on the mission phase, (e.g., take off, ingress, attack, egress, or landing).

Mission effectiveness is increased by increasing attack effectiveness and survivability. Deconfliction in the target area is required because the means to increase mission effectiveness conflict:

- Attack effectiveness and survivability increase if saturation can be obtained. By concentrating one's assets in a small area within a short time span it is hoped that the enemy will be too confused to defend himself effectively.
- Survivability also increases by attacking at the lowest levels that are possible without flying through the fragmentation of exploding armament.

Some of the systems that we reviewed claim to deconflict in the target area. Fragmentation envelope deconfliction is limited to deconfliction with one's own armament. It appears to be irrelevant to helicopter operations and has not been implemented in planning systems dedicated to rotary wing operations (e.g. HOP).

Deconfliction with other friendly air assets in the target area has been implemented in ISMP, TAMPS, and CAMPAL. ISMP checks the route and time of arrival of each vehicle to prevent in flight conflicts. TAMPS deconflicts with cruise missiles and differentiates the routes for multiple aircraft in a given mission area by displaying them with different colors. CAMPAL displays a matrix with differences between the time of arrival of the individual aircraft in a force at the initial point, pull-up point, and at the desired mean point of impact.

Deconfliction with other friendly forces enroute is handled quite differently. Preflight enroute deconfliction is only performed by tasking agencies (time slots, like TOT and ACOs) and regional air traffic control agencies that ensure that there are no conflicts with other friendly air resources in the area of operation. At the wing level, TAMPS seems to be the only pre flight planning system that differentiates the routes for multiple aircraft in a given mission area by displaying them with different colors (though route deconfliction must be done manually by viewing the color display for overlapping route segments). In flight deconfliction is not planned pre flight but is typically based on the pilot's use of visual contact to ensure adequate spatial separation.

Deconfliction during takeoff and landing is performed by the local air traffic agencies; it is not incorporated in any of the pre flight mission planning systems that were reviewed within the context of this study.

5.8. MISSION REHEARSAL.

A level of mission rehearsal capability is embedded in all emerging mission planning systems. However, in most cases, it is restricted to displaying photographic or sensor images of portions of the mission, particularly in the area of the target. In some cases, mission planning systems have the the capacity to generate static terrain images from digital terrain data that can be viewed from different orientations. For some systems (e.g., TAMPS) rehearsal is an integrated part of the planning process; once the mission has been planned, rehearsal is used in an iterative process to optimize the mission with respect to attrition and survivability.

Some mission planning systems provide the capability to simulate the mission; the simulation can be run at various speeds (e.g., slower than real-time, real-time, faster than real-time). This allows the crew to become familiar with the most critical phases of the mission by rehearsing faster than real-time in the noncritical mission phases and rehearsing real-time in the critical phases. Currently, no mission planning system has the capability of performing mission simulation in real-time while providing 3D bird's eye terrain images. This capability is expected to be important for future systems. Input of unplanned events to mission rehearsal simulations is not yet a feature of the emerging mission planning systems. However, this capability will become important for future systems as in-flight mission planning systems become integrated into the avionics of military aircraft.

5.9. GROWTH POTENTIAL.

The growth potential of emerging systems can be discussed in three different categories. First, emerging systems tend to have the capability be linked to C^3 networks. This will speed up the data gathering process during plan preparation because the latest intelligence information will be readily available. C^3 networks may also be used to transmit pre-planned missions coming from a higher level in the command structure.

A second extension to mission planning systems is the ability to couple them with knowledge-based systems that may assist the pilot in the pre-flight computation of the mission plan and exploring alternatives.

Finally, emerging systems tend to use commercial hardware to support mission planning systems. This allows the systems to benefit from new hardware and software upgrades thus allowing their capability to evolve into the future.

Chapter 6
Future Mission Planning Systems

The requirements of future mission planning systems will remain fundamentally the same as for emerging systems. However, the demands made upon their capabilities may increase as demands upon the weapon system as a whole increase due to the presence of more capable threats. Furthermore, whole requirements may alter as experience is gained with the emerging mission planning systems.

Developing technologies such as AI will be employed to reduce crew work load by increasing the level of automation. The increased automation capability of the mission planning system will require careful consideration to ensure that the division of tasks between the operator and machine is optimal. This Section reviews the criteria identified as important for both ground-based and in-flight automated mission planning systems.

6.1. GROUND-BASED MISSION PLANNING.

6.1.1. Interoperability.

The lack of proper interoperability characteristics is a major impediment to the use of current mission planning systems within the context of combined NATO forces or NATO operations. Because these characteristics are not fully available in current and emerging systems, it is not possible for aircraft from one NATO country to use facilities available at other NATO country airfields. The significance of this lack of interoperability has been recognized by NAFAG who have set up a series of meetings to discuss and resolve the problem.

There appears to be no fundamental reason why, in future systems, a much greater degree of interoperability could not be provided. As noted in 5.1, this would require the adaptation and maintenance of standards for mission planning hardware and software interfaces. In addition, the adoption of common human standards for formats, keyboards, displays, etc., would be highly desirable if the performance of visiting aircrew in the mission planning process is not to be degraded. National sensitivities may preclude the full integration of all the MPS features into a NATO mission planning standard, but it should be possible to provide a basic "minimum standard" of capabilities that would allow the essential function of planning and loading mission data to be prepared. For such basic functions it may be desirable to use commercially available, open system software that could be hosted on a range of host computers.

6.1.2. Database.

The description given in 5.2 of the data used in current and emerging mission planning systems is generally applicable to the requirements for future mission planning systems. But the improvements in computer power, data storage capabilities and in the techniques of artificial intelligence and rule-based computing all suggest that some future growth in database requirements is likely. The following Sections suggest areas of change as compared with the equivalent Sections 5.2.1 to 5.2.4.

6.1.2.1. Geographical and Meteorological Data.

Future systems are likely to have increased capability to represent to the aircrew the visual scene from the aircraft as it flies through the mission, particularly during critical phases such as operating in the target area. This implies that the terrain and cultural data must have higher resolution then is currently available. It is becoming possible to integrate together such data with image data obtained from satellite or aircraft reconnaissance, and the storage and processing of such data will become an increasingly important part of future systems. Image data to be used in this way will be of long term validity and will be stored in a library in the form of photographs; other data will be of transient value and will require to be sorted and processed very rapidly after being obtained from satellite or reconnaissance aircraft missions.

6.1.2.2. Data on Friendly Assets.

Little change is expected in this area.

6.1.2.3. Data on Missions and Tactics.

The move towards increasing capability for automation of the planning process implies that tactics will have to be represented in a formal way, that can be used in rule-based computations.

6.1.2.4. Data on Enemy Assets.

The need for rapid updating of information on the enemy's mobile assets implies that in some cases the communication and filtering process may take so long that the information's validity may be seriously degraded. In such cases it may be appropriate to consider direct communication links between the mission planning system and reconnaissance sources. Information flow of this type will always require some elements of filtering and collation and increasingly this will become possible within the mission planning system itself.

6.1.3. Communication.

Communications will continue to be a critical area in determining the required characteristics of future mission planning systems. The capability of ground-based, airborne and spaceborne sensors to gather data on the enemy's assets is likely to increase, with the corresponding need to process and distribute the data to the ground-based mission planning stations. This distribution will form part of the total communications, command, and control structure that will be needed for the operation of airborne assets. Such a structure will be required to operate with some performance degradation, even when elements are malfunctioning or non-functioning due to damage inflicted by the enemy. It may also be necessary to have the capability to relocate the mission planning function within the C^3 network to allow for damage to local mission planning workstations or to the communication links. The current practice of loading data into the aircraft by the use of cartridges needs to be re-examined in this context.

6.1.4. Time.

Mission planning is a process that takes time. In most military scenarios, time will be in very short supply. It is therefore critical that future mission planning systems enable the mission planner to generate missions within the time constraints imposed by the prevailing tactical situation.

Time constraints imposed upon the planning process are primarily a function of the mission. Referring to the four missions that were reviewed in Section 2.1, recall that for some tactical missions (e.g., deep interdiction,) the time available for mission planning is measured in hours, while for other missions (e.g., close-air support,) the time available for mission planning is measured in minutes. Even within the same mission class, the amount of time available for planning can vary from mission to mission. For example, for the close-air support mission the time available to plan can range from 2 to 30 minutes depending on the tactical situation.

There are two basic approaches for guaranteeing that mission planning can be performed within the time constraints imposed by the mission.

(1) Guarantee that the mission planning system can always generate a plan in less time than the worst case situation.

(2) Make the mission planning system flexible, so that the time required to generate a mission plan can vary.

The first approach has two major defects. First of all it assumes that a worst case (minimum time) scenario can be identified for each mission. If for example we assume that for the close air-support mission there will always be 5 minutes available to plan the mission, we are in deep trouble if we are ever faced with a situation in which there is only 4 minutes to plan. The second approach is more flexible It allows the mission planner to spend more time planning the mission when time is available (theoretically enabling the planner to do a better job) and yet is still capable of generating a mission plan when time is limited. Of the two approaches, the second is the more desirable. Future mission planning systems should provide the capability to function in variable planning time.

6.1.5. Flexibility.

Flexibility will continue to be a critical area for design of future mission planning systems (MPS). Future systems will need increased focus on the software interface that links the system user to application software via hardware interfaces, i.e., displays and controls. The importance of the software interface is underscored by the fact that a modern hardware interface is driven by software, and that the software is the medium for dialogue between the user and the application system. The function of the software interface is to recognize events at the hardware interface and at the applications interface; then, translate these events from one side of the interface to the other. Research focused on the development of design guidelines to insure compatibility of software interface features (e.g., device handlers, event presenters/recognizers, dialogue controllers, and data filters) with MPS goals and user characteristics is essential for improved speed and accuracy of MPS use as well as to facilitate adaptation of MPS to situational demands.

6.1.6. Ergonomics.

6.1.6.1. Introduction.

Based upon our evaluation of current mission planning systems, the following observations can be made.

(1) There is still a large reliance on maps, pens, and paper.

(2) The integration of pertinent mission information is still largely a manual task performed by the aircrew.

(3) The manual aspects of mission planning are important as a mission rehearsal function in that the process itself provides the aircrew with a detailed appreciation of many facets of the mission. With highly automated systems, this appreciation may be lost, particularly if no means for an in depth examination of the plan or for some form of mission rehearsal are provided.

(4) Much time is spent on entering relatively mundane information, such as communication frequencies, waypoint coordinates, etc.

(5) Mission plans constructed over a period of time tend to be more sophisticated than those done in hurry. As a consequence some of the more elaborate features that would improve combat effectiveness and survivability are lost when there is only a limited time available for planning. Furthermore, re-planning in-flight cannot be done to the same level of sophistication, with the same consequences.

Based upon our evaluation of the emerging mission planning technologies the following observations can be made.

(1) The pen and paper tasks are diminishing.

(2) There is a definite move toward the use of more centralized databases that support the integration of information and facilitate coordinated planning.

(3) Facilities for a limited form of mission rehearsal and for the preview of important intelligence information (e.g., FLIR and radar imagery) are emerging as important feature of some systems.

(4) There is clearly a reduction in the manual tasks associated with the entry of radio frequencies, safe corridors, IFF codes, etc.

(5) Emerging systems enable a reduction in mission planning times on the ground and transfer facilities (cassette or direct link) have been developed that can rapidly transfer this information into on-board systems.

(6) In-flight mission planning systems are still at the laboratory stage.

The key feature with significance for the future is the move toward computer based systems, that will place reliance upon some form of centralized database. From the human factors standpoint there are consequently two significant aspects that will affect the development of future systems; these are:

(1) The importance of ensuring that the user's needs are adequately represented during the system design process.

(2) The importance of establishing the relevant criteria upon which to base the interface design.

The latter aspect is of great importance. It is likely that future systems will be highly capable, with a variety of features and with potentially some form of decision making capability. The success of the whole system in such circumstances will be impacted by the design of the user interface.

6.1.6.2. Criteria

A short description is provided of some of the criteria that should be taken into account in the design of a user-oriented interface. Despite the differences between the human-machine interfaces of the on-ground and in-flight mission planning systems, the interfaces should be designed as parts of a total system. The criteria utilized to develop both interfaces should remain valid across interface designs, but may drive the design toward different mechanizations due to the operating environments of the on-ground and in-flight mission planning systems. Characteristics of the two operating environments that are different include speed of mission re-planning, vulnerability, number of concurrent tasks, etc.

(1) Levels of Automation. The level of automation should be based upon a general principle of "human-automation compatibility". This principle states that monitoring and control functions should be dynamically balanced based upon the workload, capabilities, and tasking of the operator. The levels must differentiate between preflight and in-flight tasks.

(2) Capability to react quickly to a variety of inputs. The mission planning systems should provide at all times rapid access to any of the information held on the database to which the user has authorized access. This means that the system should be able to process in parallel commands coming from different inputs, such as a keyboard, a mouse, a trackball, a touch-screen, or a voice input.

(3) Menu driven. The specific requirement is for a menu driven interface as opposed to command driven. Menu type interfaces require only a short learning period for the user to become proficient. A potential drawback, however, is that experienced users can find the interface slow and tedious unless careful design allows the interface to adapt to use by experienced users. Some tasks, e.g., entry of meteorological data, are more suited to form filling type dialogues. WIMP type interfaces should be able to combine different forms of interface where appropriate to the task and user. Menus should help the user know where he is in the planning process, back up easily to previous steps as needed, and start over quickly from the beginning as desired.

(4) Quick and consistent Feedback. The user should be given the opportunity to interrupt his task to obtain feedback on the tasks completed. This means that the interface should be able to display the results of the sub-tasks, under the control of the user.

(5) Transparency. This criterion concerns the user understanding of the process that produces the automated planning solutions. This means that the interface should display, on request, the respective relationships between the solutions and the rationale by which they were derived. Therefore the user should be able to understand the decision process, by being able to understand and evaluate the rules and knowledge that the systems uses. Furthermore, the interface should reflect the intentions of the user by representing the mental schema or model of the user.

(6) Reduction of Semantic Distance. This is the cognitive model and control that the user has of the decision making process by which the system derives its solutions. It is essential that this model matches that of the machine process to reduce the workload demand imposed on information interpretation and error reduction. The system should be transparent and the rules should be represented on the interface in an unambiguous way. Symbols and icons must be self evident in their meaning.

(7) Error Detection and Correction. The automation of certain mission planning tasks will not reduce the occurrence of operator errors. It is therefore desirable that the system be designed to both reduce the occurrence of errors as well as be fault tolerant. For example, all manual actions should be able to be changed and the user should be able to view the consequences of such actions. The user, via his cognitive model, should be able to predict the consequences of each action and where necessary update his model. The system should be able to validate inputs and highlight those that are incorrect, while aiding in their correction (although this would depend on the form of the error). This form of input verification can be utilized at higher levels by use of expert systems techniques that would, in collaboration with other systems, analyze the feasibility of a command and verify and monitor the consistency of decisions. An "undo" facility should be provided so that the user can easily recover from an unintended operation.

(8) Weighting Rules. In mission planning systems that utilize formalized knowledge and artificial intelligence techniques, different emphasis may be applied to rules or parameters to affect the outcome of planning. The weighting must be easily changed.

6.1.7. Deconfliction.

At present, only intra-force deconfliction on spacing between aircraft (and fragmentation of their weapons) and between aircraft and cruise missiles is handled in pre-flight mission planning systems. Deconfliction across nations (and even across services, e.g., Army, Navy, Air Force) is performed by higher command and control echelons. Future developments may well incorporate these capabilities into wing-level mission planning systems as well.

Feedback of mission plans to higher command and control echelons must be an essential requirement for future systems as only then can deconfliction be performed by individual planning systems without the requirement to interface with command and control elements. Because of the rapidly changing situations on the battlefield, deconfliction with other forces is only possible if last minute updates can be made in flight via JTIDS or MIDs type systems.

6.1.8. Mission Rehearsal.

The capability to rehearse the planned mission or a single segment as soon as its planned can be considered as an optional feature, but a minimum rehearsal capability should be included as a basic function, particularly the capability of examining the mission or its segments to verify (automatically as far as possible, but always under operator's control) that no mistakes are presents in the final plan. This feature could be defined as:

- Add friendly, interactive debugging capability. Mission rehearsal can be aimed to other two objectives:
  - mission optimization, through the possible identification of better solutions
  - crew training for that specific mission.

The Pre-Flight mission planning system might consist of several rapidly reconfigurable cockpits that would serve as workstations for non-flight activities as well as cockpit structures for mission

rehearsal. It is conceivable that this cockpit would allow the pilot to interactively plan his mission in a workstation environment, fly the mission just planned from take-off, interrupt the mission in mid-course to change some parameters, return to the mission rehearsal mode to complete the mission, re-fly the mission from take-off to landing, and then produce the mission data cartridge to be taken to the aircraft. Several cockpits would be required to support multiple aircraft flying the same mission. Mission planning and mission rehearsal could be performed simultaneously with all pilots.

6.1.8.1. Mission Plan Debugging.

Errors that can affect the final mission plan can be of different types:

- Wrong Input Data. Wrong data can either be included in the data bases used for planning or be input manually by the operator.
- Invalid Assumptions. some general statements that are considered during the planning process could be not applicable to some specific cases.

A stepwise mission rehearsal procedure that automatically verifies congruity of evolving mission status, submitting on operators request criteria and data used and flexible enough to easily accept any change for re-planning could be a useful debugging tool. Extensive use should be made of pictorial displays and easy input media to allow quick and safe execution of this phase.

6.1.8.2. Mission Optimization.

The achievable level of optimization is probably dependant on the time available for this phase. The optimization can be addressed to factors like:

- reduction of risk exposure
- reduction of pilots workload and possible errors
- reduction of active signature (emissions)
- reduction of mission time
- increase of attack effectiveness
- economy of expendables (including fuel)
- improvement of deconfliction
- integration with other missions on the same or adjacent target (s)
- improvement of flight safety.

Automatic computation of such parameters, when possible, should take place during the planning phase and means to parametrically evaluate them during rehearsal should be provided. A 3D color graphic display should provide a computer generated out of the window scene prediction from view-points on the planned flight path that can be moved and steered around.

This facility is desirable for target, visual route points, critical areas, etc. Simultaneously, when applicable, on board sensors displays should be replicated showing sensor images prediction. A digitized images storage capacity should also be provided, to allow real photographs to be reviewed, when available. In this context, the mission or portions of it could be virtually "flown" in an operator controlled slow/fast/real time and reviewed by:

- the mission planning operator
- the pilot (may not be the same person)
- a senior pilot/advisor

and by an automatic evaluator that applying general rules should be able to rate the different solutions in terms of effectiveness, survivability, etc.

6.1.8.3. Rehearsal for Training.

Mission rehearsal shall also be used for training crews. In this case it can take place in a wide range of different forms. Synthetic generation of images of what the crew is going to see both out of the window and on the aircraft displays (radar, IR, LLTV, etc.), integrated when possible with real images from any available source is of course an important support to training for that mission, as well as for the study of optimized solutions, as discussed before.

Another important form of training is for the crew to familiarize with the sequence of actions and with the timing of that particular mission; for this purpose the planned mission could be flown automatically - in terms of basic aircraft control - in a CPS (cockpit procedure simulator) whilst the crew interacts with cockpit displays and controls and becomes familiar with sensors management, communications, weapons selections, attack procedures, etc.

The ultimate step of training could be to perform the whole mission in a full mission simulator where it could take place exactly as planned or where a number of possible changes and unforeseen situations could occur, including those requiring in flight re-planning of the mission itself.

6.1.9. Growth Potential.

Requirements for future mission planning systems are broken down into four categories. Regarding hardware, new mission planning systems should use standard commercial hardware adapted to military needs, to allow easy evolution and continuity of hardware, software, and interoperability. Artificial Intelligence should have a role in future mission planning systems. Libraries of missions should be maintained in order to reuse parts of a mission that have already been generated. Finally future mission planning systems should not be thought of as ground-based systems, but as parts of a more complex structure including in-flight mission planning systems.

6.2. AIRBORNE MISSION PLANNING.

The Mission Planning function is conventionally thought of as being a pre-flight activity that is performed at a work station that is separated from the aircraft. However, the concept of in-flight on-board mission planning is not new. In current aircraft after the aircrew boards that aircraft, changes to the planned mission can be accomplished by modifying the planning data as it is entered into the avionics system or by editing the data after it has been loaded into the avionics. The modification of planning data by the aircrew, or re-planning, is on-board mission planning, and, if it is done while airborne, the modification can be considered in-flight on-board mission planning. In the future, the capabilities of the in-flight on-board mission planning function can be greatly extended in terms of functionality and capacity. In-flight on-board mission planning differs from pre-flight mission planning in that the capability of

future in-flight on-board mission planning system will be tailored to the constraints imposed by the flight environment, such as time pressures on the aircrew, limited space and power availability, number of aircrew members, and the use of flight qualified control and display devices. Mission planning for "dynamic" tactical missions, such as close air support, may require advanced in-flight re-planning on-board the aircraft to effectively perform the mission or to even make the mission possible.

6.2.1. In-Flight Interoperability.

It is expected that future in-flight mission planning systems will be implemented as integral parts of the avionics suites of the aircraft in which they are fitted. Consequently, interoperability will be restricted to ensuring that the necessary mission planning information is available, and that the resultant plans can be rapidly disseminated to applicable friendly forces. Communication issues, as noted in Section 6.2.3, are therefore of major significance. For single-seat tactical aircraft, particularly, it will be necessary to minimize the workload associated with establishing the communication links in-flight, and the need to maintain security and covertness will inhibit the amount of data exchange.

6.2.2. In-Flight Database Issues.

The data generated by the pre-flight mission planner and loaded into the aircraft prior to commencement of the mission is usually that necessary to execute both the mission and a few pre-planned alternatives. This will include a significant part, but not all, of the total data available to the pre-flight mission planning system. Table 5-1 shows the information that is typically output from the pre-flight mission planning system that will include routes, timings, IPs, fuel load etc.

If a degree of re-planning is to be carried out in flight, additional information will need to be loaded into the aircraft for in-flight use. The amount of additional information will be directly related to the extent of re-planning allowed for. It is unlikely that additional geographic or weather data would be required, except that, for missions of long duration, a weather update may become available and useful. Updates on the disposition of friendly assets may also be used.

It will be seen from Table 5-1 that no data on missions and tactics need be loaded into the aircraft if re-planning is not required, but if re-planning is to be carried out in-flight then data on available corridors and IPs will need to be updated in flight. Similarly, as well as carrying and receiving updated information on enemy threats and targets, the in-flight re-planner will need to use available knowledge on enemy tactics.

The amount of additional data that will be required is thus relatively small and unlikely to present a problem in terms of storage. There could, however, be substantial difficulties in providing satisfactory data updates in-flight, particularly as information on enemy movements may be of uncertain quality. The correlation and filtering that is normally carried out on the ground may not be within the capability of the aircrew in flight, and the quality of in-flight re-planning may be seriously degraded by inaccurate information.

6.2.3. In-Flight Communication Issues.

The In-Flight part of the mission planning system would be an integral part of the on-board avionics system. In a single place aircraft, the operation of the mission planning system would be controlled by switches placed on the stick and throttle. The system would allow for limited mission rehearsal (i.e. for air-to-ground, a target run in sequence) and would permit the pilot to interactively control the remaining portion of the flight. The system would present options to the pilot for selection and would allow the pilot to manipulate tactical decisions and outcomes and not require the pilot to mentally compute items such as fuel remaining or ordnance delivery requirements. The system would via a data link receive changes in the threat environment and the mission status of other friendly aircraft as well as transmitting aircraft mission status to the other friendly aircraft. Increased in-flight planning and re-planning capability could require more communication with differing security requirements.

6.2.4. In-Flight Time Issues.

In-flight planning will require faster computations of planning parameters and simplified control and display utilization than pre-flight operations.

6.2.5. In-Flight Flexibility Issues.

The flexibility required of the in-flight mission planning system will be both greater and lesser than that required for the ground based system. The interface to the pilot must be more automated, and thus provide fewer options to the pilot, it must be flexible in its solutions to planning situations. If the in-flight systems always responds in a predictable fashion to enemy actions, for instance, the enemy can utilize this predictability against the friendly forces.

6.2.6. In-Flight Ergonomic Issues.

6.2.6.1. Management of Cockpit Priorities.

Mission re-planning in-flight has to be managed and put into relationship with the other cockpit activities in order to avoid dangerous interferences. Any significant breakdown in the mission has important implications for the pilot's activities. The pilot is rapidly involved in the cognitive task of updating his mental schema and his current situational priorities. When re-planning must occur the coordination of activities is based on a careful balance between two different requirements, namely the rapid evaluation of what has to be changed in the plan and the continuation of critical activities in the cockpit.

An automated planning system can fruitfully assist this coordination task either by accelerating the process or by intelligently augmenting pilot capabilities.

6.2.6.2. Re-planning Decision Aids.

It is possible for the in-flight mission planner to evaluate objectively the thresholds that suggest whether to change the planned mission once it has been started. Objective evaluation is the result of rules, usually not explicitly stated in reference manuals and in Air Force regulations but learned by the pilots during the training process. These rules help the pilot to decide, for example, how to cope with overcoming threats that might affect the mission, how to face emergencies without compromising safety limits, etc. It is a direct derivation of the known limits of: the type of aircraft, the complexity and the timing of the mission and, more generally, any important constraints evaluated as necessary for the success of the mission.

The existence of these limits gives rise to careful consideration on how to utilize them during the design process. This may be some sort of automated assistance that relieves the pilot of part of this decision task. The important point is, however, that the pilot might find himself uncertain while deciding whether the plan has to be changed and to what extent. Predictions of the implications of re-planning should be made available to the pilot along with explanations of how those predictions were obtained.

6.2.6.3. Monitoring Planning Decisions.

An important consideration in the mission planning process is that changes to one segment of the mission will have implications for the entire mission. An important example is time-over-target. Time-over-target is one of the constraints that must be maintained even when the decision to change the planned mission has to be taken, unless it results from a new battlefield situation.

Given the unpredictable timing of the arrival of the information that may cause the plan to change (i.e., it can arrive early during the mission but also at an advanced stage) it is even more important than in on-ground planning that in-flight the pilot will be able to select the desired level and possibly method of interaction with the planning system. It is critical that the automated assistance is adaptive, taking into account, on one side, the level of detail the pilot wants to explore the implications of the modification.

6.2.6.4. Display and Control of Planning Results.

The decision to modify significantly a plan might imply a change in the level of complexity of the mission. The time available to insert new data, to make evaluations necessary to change the plan and to establish a new route might not be sufficient to accomplish the further task of verifying the plan. For example, the pilot's selected route to the target might be affected. Given the short time resources, plan review is often not permitted.

An airborne mission planning system may detect and correct errors or make a quick evaluation of the trade offs among different routes. Of course, the pilot may not accept solutions and suggestions without having a clear understanding of how they have been reached.

Another relevant point to be carefully considered in the design of airborne mission planning systems is that displays and controls have to be appropriate to the pilot's operational needs. This means that consistency between the philosophy of information presentation and the philosophy of automated assistance is of primary importance.

The modes of control on mission planning tasks and subtasks could be modified in real-time according to the task time-load. In fact, time available and subjective time appraisal to perform tasks seem to be the two pertinent criteria pilots use to share these attentive resources among subtasks. It is thus preferred that automation assistance also be determined on the basis of such criteria.

6.2.7. In-Flight Deconfliction Issues.

Changes in a mission plan will require some aspects to be disseminated to other aircraft in the air and to ground-based mission planning systems to permit deconfliction. This is especially true of airborne aircraft in the same general area. Deconfliction may be done on the other aircraft in an automated way to reduce aircrew workload. It is possible that the plan of one aircraft is dependent on the actions of a second aircraft. This functional coupling requires a decision process and communications system capable of disseminating the revised in-flight mission plans to the appropriate aircraft.

6.2.8. In-Flight Mission Rehearsal.

It is likely that in most tactical aircraft, in-flight mission rehearsal would not be utilized in an actual mission context. In-flight mission rehearsal may have a place before take-off, during engine run-up and pre-flight if time permits. During the flight, the only potential use of mission rehearsal might be for embedded training, but this is only for peace-time training and not in an actual mission context.

6.2.9. In-Flight Deconfliction Issues.

The growth potential for in-flight mission planning is only a fraction of the growth potential for pre-flight, ground based systems. Any modifications to the airborne avionics must be validated before it is released to the fleet and this testing is more complex, and rigorous than its ground based counterpart.

Chapter 7
Conclusions for Phase One

The major focus of the Phase One effort was to assess the current state of mission planning technology in the various NATO countries. Our objective was to identify the existing capabilities, both strengths and weaknesses of current mission planning technology. We set out to achieve this objective by first establishing a set of performance characteristics and then proceeded to assess both existing mission planning procedures and emerging mission planning systems using the performance characteristics.

A review of the mission requirements for four tactical aircraft missions (air defense, close-air support, air interdiction, and attack helicopter) lead to the development of nine performance characteristics. The characteristics are:

(1) Interoperability

(2) Database

(3) Communication

(4) Time

(5) Flexibility

(6) Ergonomics

(7) Deconfliction

(8) Mission Rehearsal

(9) Growth Potential

These characteristics were then used to evaluate the mission planning procedures currently being used for the four aircraft missions described above. The major conclusion from this investigation was:

- Existing mission planning procedures are extremely labor intensive. Much of the planning is done using grease pencils and paper maps; fuel and timing calculations must be performed by hand; and mission related data must often be entered into the aircraft by hand.

It became clear that mission planning doctrine and technology has lagged far behind many of the aircraft technology developments since World War II.

Most of the NATO countries have also come to this conclusion as our investigation of emerging mission planning technologies revealed a large number of efforts underway to develop computer-based mission planning systems. After reviewing the existing mission planning procedures the Working Group proceeded with the major effort for Phase One: the investigation of these emerging mission planning systems. This investigation looked at a wide cross section of emerging mission planning systems from a variety of NATO countries including:

• AAFMPS	U.S. Air Force
• AMPA	United Kingdom R.A.F
• AMPS	U.S. Army
• CAMPAL	Netherlands R.N.L.A.F.
• CINNA 3	French Air Force
• CIRCE 2000	French Air Force
• MARPLES	Italian Air Force
• TAMPS	U.S. Navy
• TEAMS	U.S. Navy

In general these emerging mission planning systems are built around a computer workstation coupled with a high-resolution color graphics monitor. Although capabilities vary from system to system most of the emerging systems provide the following capabilities:

- Digital map displays.
- Threat overlays.
- Automated computation of fuel consumption and ETA at each waypoint.
- Graphical input of waypoints using a mouse, trackball or joystick
- Route planning functions that perform intervisibility computations to generate the safest routes.
- Large mission planning databases of that include: digital terrain elevation data (DTED); operational and pilot reports; weather data; threat locations; and locations of friendly and enemy forces.
- Hand held cartridges for transfering mission planning data into the aircraft.

In addition the following capabilities, although less common, were provided in some of the systems:

- Radar, satellite, and IR imagery of the target area.
- Real-time and faster than real-time mission rehearsal.
- Deconfliction.

During this analysis, a major observation that came out of the Phase One effort was that the focus for the emerging planning systems is on ground-based, pre-flight planning technology. Limited effort is currently in progress to develop in-flight mission planning systems. The Working Group felt that in-flight planning capability will become increasingly important for future mission planning systems. A number of in-flight capabilities were identified that will be addressed in Phase Two (See Chapter 8).

Chapter 8
Potential Phase Two Topics

8.1. INTRODUCTION.

The Working Group's Phase One studies concentrated upon current and emerging systems and hence were largely concerned with systems that carry out the planning task in workstations on the ground, before commencement of the flight. Phase Two will be directed towards future possibilities and will assess both the potential value of new systems in the context of specific operational scenarios and the research and development to bring them into use. Future systems can be envisioned that conceptually will be much less constrained than present systems and may consist of networks in which some mission planning capability may be based and installed within the aircraft. It also appears likely that mission planning and re-planning will be carried out both before commencement of a mission and after takeoff.

In the remainder of Chapter 8 are listed the topics that the working Group identified during Phase One as being potentially worthy of study in Phase Two and consistent with the wider concepts outlined above. It will be seen that the list is a long one (although not necessarily exhaustive), indicating that there are many possibilities for expansion of the role of future mission planning systems beyond their present capabilities. The topics have not been arranged in any order of priority; it will be the task of Phase Two to assess their relative importance and perhaps to add further topics as the study progresses.

8.2. SYSTEM CONCEPTS.

Distributed Mission Planning Process. The mission plan or its modifications can be the result of a process involving several stations and responsibilities both before and after mission launch. The resulting plan can be in this way very effective, up-to-date and reliable, provided the system upstream of the final output is tolerant and flexible.

Dynamic Prediction of Battle Evolution. This may be possible if intelligence data is available and the system has a real-time war-gaming capability; AI techniques are foreseen to be one method of achieving this capability. Such prediction capability can be useful in collecting appropriate information and in setting up databases to meet possible re-planning needs and to adopt proper tactics.

Interoperability. This concept has already been investigated during Phase One of the Working Group but the interest shown by NATO on this topic indicates that further examination is still required. In particular, the concept of distributed mission planning processes working within a C^3 network raises many inter-operability issues.

Airborne Mission Planning. The concept of modular avionics recently developed for the ATF is likely to be adopted by future aircraft; this emphasizes that the on-board mission planning function shall not be of a stand-alone type but will be embedded and share other aircraft functions, not only avionics. Also in this case, it is foreseeable that such integration can take advantage of AI techniques (e.g., cooperating expert systems).

Mission Rehearsal. The primary function of mission rehearsal is to increase mission effectiveness by allowing the aircrew to become more familiar with all or part of the mission (specifically the critical parts) that is currently being planned. Mission rehearsal can also be used to test the ability of an aircrew to perform a mission that was planned by another crew. An aircrew may test its ability to perform a given plan while the mission rehearsal system may acquire some characteristics of the aircrew to be integrated in the mission planning system.

In order for mission rehearsal to be effective, it should provide the user with fixed or moving imagery of different types (visual, radar, IR, computer-generated, etc.) and should offer more or less realistic or detailed views according to collected data and aircrew needs. According to the goal of the aircrew, such a system would offer different levels of interaction ranging from previewing images or mission phases, to full interaction with an aircraft simulation, allowing the crew to test alternative paths to the target or avoidance maneuvers in the case of new threats.

Mission rehearsal may be used at any step in the planning process in order to test a just computed critical phase or at the end of the planning process to review part or all of the mission. The rehearsal itself should be able to run at different rates, slower than real-time for examining critical phases, real-time for evaluating workload or time pressures, to faster than real-time for rough evaluation or for in-flight use.

8.3. SYSTEM TECHNIQUES.

Data Filtering/Fusion. Filtering and fusion of data for mission planning systems is required to reduce the total amount of information and combine (different) information from different sources and to eliminate inaccurate data.

Data Protection. In-flight on-board planning on the basis of externally supplied data (or plans), or pre-flight planning on the basis of data from external sources, requires that the mission planner have access to highly sensitive information. The storage of this data in a mission planning system has to be such that the data is:

- Automatically destroyed after a crash (or capture) in the case of an on-board system, and
- protected against unauthorized access in the case of a ground-based mission planning system.

Communication. The concept of a networked (ground-based and/or airborne) mission planning system and data sources implies communication links between workstations. Though the availability of communication is increasing, (e.g., satellites) these communications and data links have to be secure and unjammable, and may not always be useable because of covertness requirements.

Testing/Validation. Testing and validation will be performed by the system developer before the system is fielded, as well as by the end user during each mission planning session. Pre-flight testing can be highly interactive, but in-flight testing will be much more automated. The likely possibility of the use of AI

knowledge based technology within the airborne mission planning system in conjunction with uncertain information and asynchronous events, will increase the complexity of testing and validation. The mission planning system will need to produce plans that are not predictable to the enemy. This non-predictability also complicates the testing and validation of each mission plan.

Artificial Intelligence. Artificial Intelligence (AI) or similar techniques may be required to support decisions within a mission planning system, notably if it is on-board a single seat aircraft. The degree of support depends on the planning workload of a particular mission phase.

Computer Graphics. The generation of a synthesized real-world image will be increasingly important, especially in the context of mission rehearsal. Such images may be based on DTED and DFAD data bases, but also on photographic data from RECCE aircraft and satellites. Considerable computer power is needed, especially if the graphics have to be generated in real-time. The graphics hardware should be suitable for use in day and night time under various weather conditions. Future mission planning systems may require greater display capabilities than presently available.

System Architectures. Future mission planning systems will generally become more capable, more complex, and have increasing ability for intercommunication with other components in a networked C^3I system. Consequently, the architecture of any future mission planning system, must allow for progressive change and update, to take account of the changes that will occur to the elements of such networks, and also take advantage of improvements in the state of the art in mission planning technology. This implies that the architecture should be based on a series of modules that can be developed and modified independently, thereby minimizing the cost and difficulty of both maintenance and update.

The modular concept has the advantage that, in responding to a requirement for a new mission planning system, the developer should be able to utilize a significant number of modules developed under previous programs. It also has the advantages in making it more easy to insure that interoperability between different mission planning systems and different aircraft can be achieved. To achieve these advantages requires that the software, communication, and system standards are agreed to and supported. This could create major difficulties, especially in those areas in which technical advances are being made under commercially funded developments.

It is highly likely that, in the more complex mission planning systems, both hardware and software will be built up in a modular fashion. The single single CPU system shown in Figure 2-1. will be replaced by a number of dedicated computers, each working on only a part of the overall computational load. As an example of this, a dedicated graphics processor will be needed to provide the processing throughput required for real-time generation of highly realistic maps and 3-D images. It can be expected that many of the algorithms and the rules required in on-board mission planning systems will be similar to those used in pre-flight planning. The extent to which the same software packages can be used in both applications will require further study.

Man/System Design. Increasing automation, design of higher level tasks into the avionics of mission planning systems, and psychophysiological limitations of system operators raise issues of: crew trust and confidence in the planning process, impact of operator fatigue on the planning process, mission execution, effect of environmental factors on mission success, relationship of operator skill level to speed and accuracy of the planning and mission execution process, and role of electro-optical systems (helmet mounted systems, virtual image display systems) in the planned mission functions. Consideration of these issues extends the concept of ergonomics in Section 3.2.6 but are considered integral to the successful planning and execution of the mission.

All topics above refer to both ground-based and airborne mission planning systems. A more refined analysis will reveal the commonalities and differences between these two types of mission planning systems, but weight and space constraints will always make an airborne planning system less capable than its ground-based counterpart. Subsequent studies have to determine the acceptability level of such reduced capabilities, in order to make airborne mission planning systems as effective as possible.

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Appendix A
Survey of Emerging Mission Planning Systems

In the past decade, the tremendous growth in computer technology has made it possible to automate many of the mission planning functions that in past years were performed by hand. Many automated mission planning systems are currently being developed that offer the potential for mission planning to be done faster, more effectively and with reduced errors. In this Section, we will review the emerging automated mission planning systems. First we give a description of nine mission planning systems that were selected as representative of the types of systems under development. Subsequently, we review these systems in terms of their applications, implementation and capabilities. During the review, the similarities and differences of the systems are discussed.

A.1 AUTOMATED MISSION PLANNING SYSTEMS.

A survey of the NATO countries will quickly confirm that there is a tremendous effort underway to develop and deploy automated mission planning systems for tactical aircraft missions. We have selected to review 9 systems that are being developed or have recently been deployed. These systems represent work underway in the five countries participating in the working group, France, Italy, the Netherlands, the United Kingdom and the United States. However, automated mission planning systems are also under development in other NATO nations.

The 9 automated mission planning systems were selected to represent a wide cross section of different aircraft and aircraft missions. The 9 systems that were selected are

- Advanced Air Force Mission Planning System (AAFMPS)
- Advanced Mission Planning Aid (AMPA)
- Automated Mission Planning System (AMPS)
- Computer Aided Mission Planning at Air Base Level (CAMPAL)
- CINNA 3
- CIRCE 2000
- Military Aircraft Route Planning Expert System (MARPLES)
- Tactical Aircraft Mission Planning System (TAMPS)
- Tactical EA-6B Mission Support (TEAMS)

A.1.1. AAFMPS.

AAFMPS is the next generation U.S. Air Force mission planning system that replaces the current mission planning capability in US fighter units consisting of flight planning and weapons delivery programs running on Zenith Z-150/248 computers, Mission Support System (MSS) I and MSS II. The capabilities of the AAFMPS have been obtained from the unclassified US Statement of Requirements Document (SORD) for mission support systems, TAF 312-87-I-A. The AAFMPS will be capable of completing the entire mission-planning process for the tactical aircrew. It will perform aircraft specific mission planning for all US TAF aircraft configurations (F/RF-4, F/EF-lll, F-15, F-16, and ATF), including weapons carried by those aircraft, at all system locations.

The AAFMPS will connect to TAF command and control systems such as EIFEL, ACCS, and Constant Watch which are directly linked to multi-national systems. AAFMPS will be capable of being interfaced via electronic communication systems throughout the TAF. The AAFMPS will accept automated electronics communication between force and unit level systems, such as intelligence, weather, ATO and imagery. This allows the user to readily accept and update weather, weapons, imagery, order of battle, and intelligence data using an automated interface. Weather data bases including both conventional weather information (ceiling, visibility, winds, hazards, etc.) and weather data necessary for the planning and operational delivery of electro-optical (TV, IR, laser) precision guided munitions and target acquisition systems are required to support the mission-planning process.

Mission data prepared by the mission planner will be loaded onto a transfer medium for subsequent initialization of on-board aircraft avionics and weapons systems programmed via the AAFMPS. Major areas requiring automated support include navigation, fuel management, weapons initialization, combat mission folder preparation, target area tactics planning, electronic combat planning, signature management, avionics initialization, target scene prediction, penetration analysis, optimum route selection, weapons delivery planning (all weapons) and recording of in-flight maintenance and operational data. The AAFMPS is envisioned as providing planning for departure, ingress, attack, egress, and recovery phases of a mission.

To allow for interoperability and the requirement to operate from other than a unit's home station, all US TAF AAFMPS locations will have complete flight planning capabilities accessible and internally available on the system for all US TAF aircraft to permit other services/allied nations to use the system. To increase unit flight planning efficiency, the AAFMPS will support at least four users simultaneously via separate keyboard/video display units connected to each main processing station. The system will use Defense Mapping Agency (DMA) standard products as input in the mission-planning process. The system will be capable of displaying maps of varying user-selectable scales. Displays will be available in theater-type data bases.

The AAFMPS should provide information required for daily peacetime aircrew training. AAFMPS will be capable of providing mission-specific information as requested by the aircrew. This information includes enemy order of battle, safe passage, airspace coordination order (ACO) information, SAR orbits, escape and evasion (E&E) safe areas. Air Tasking Order (ATO) information, such as restricted operating zones, weapons free zones, tactical/sector frequencies, fighter engagement zones, low level transit zones, FAC information, FLOT information, mode I/III squawks, missile engagement zones, base defense zones, night/IMC parallel track information,

AWACS orbits, optimized route planning and large area chart/situation overview, will be provided.

AAFMPS will be capable of providing conventional and non-conventional weapons release data, multi-ship employment with timing deconfliction, and other attack information to the user. Other provided information includes weapons fragmentation and aircraft deconfliction for multi-ship ingress/attack/egress. Deconfliction will be based on weapon fragmentation envelope and timing. AAFMPS will be capable of providing the mission-specific information for nuclear weapons, in addition to conventional weapons.

The AAFMPS will display enemy threat and friendly order of battle information to the aircrew and select a minimum risk route between two user identified points or between sets of user identified points. The algorithms will take aircraft signature modeling into account when that information is available. Additionally, the user will be able to input a desired minimum flight altitude above ground level (AGL), and then calculate the highest survivable altitude which can be flown for each leg of the route down to the minimum altitude selected by the user. The user shall be able to select any ingress altitude, and the system will compute and display the correct radar terrain mask and lethality contours. Route path and order of battle information will be stored for future retrieval. The route path optimization routine should consider factors such as aircraft type, speed, altitude, threat type, location relative to the aircraft, terrain, threat reaction time, time visible to the threat (time segments and cumulative), electronic countermeasures, and effects of multiple sites in its solution.

The AAFMPS software will use standard DMA data bases, intelligence target/turnpoint and background data inputs, and weather data inputs to depict, on a high-resolution video display, what a target/turnpoint may look like when using EO/IR sensors in flight. Hard copies of these EO/IR predictions will be available for target/turn point study, and in the combat mission folder. It will also calculate mission parameters such as acquisition, lock-on, and designation ranges and polarity, for EO/IR systems. The AAFMPS will display, on a high-resolution video display unit, aircraft specific radar predictions based on user input aircraft altitude, viewing angle, field of view, scope range, intervening terrain, and aircraft radar characteristics and radar scope mask. A hard copy of these radar predictions will be available and the prediction may be stored for future retrieval. The system will have the capability to utilize DMA DFAD to display cultural depictions for use in realistic radar predictions. The system will be able to generate synthetic aperture radar predictions as well.

The AAFMPS will prepare both full color and black and white strip maps, aircraft line-up card, weapons data card, and the navigation sequence data card. The user will be able to design the format and determine sizing of forms to satisfy local requirements using a word processor style of input. The system will be able to plan the optimum orbit placement for standoff jamming platforms such as the EF-111A and Compass Call. The algorithms will take refractive effects of the atmosphere on RF energy into account when this information is available. Given the location of these platforms, the system will display the effects of these systems on the enemy electronic order of battle.

The AAFMPS will possess selectable capability to display the effects of on-board jamming pods and expendables against the electronic order of battle with or without the presence of standoff platforms.

The AAFMPS will display a wide perspective representation of the out-the-window-view at user specified altitudes, ranges and look angles. In addition to single scene perspectives, the system shall provide a fly through capability. This capability shall provide at least the ability to define a route segment between two points and generate a sequence of scenes which can be played back for the operator creating the effect of flying along the selected route segment. The user will not have the ability to deviate from the planned route, and airspeed factors do not have to be considered.

- An AAFMPS user will have the capability to simultaneously display the ingress/egress routes of his entire composite force, and also have displays of the relative positions of all aircraft at any specified time.

- The AAFMPS should be ergonomically designed to allow rapid input/output of data while operators are wearing a chemical warfare defense ensemble.

The digital terrain map/display will be capable of being electronically updated at the unit level on a routine basis. The following information will be provided to the user for the Combat Mission Folder preparation: highest leg obstacle, minimum enroute altitudes(day/night), all obstacles above selected penetration altitudes, minimum and emergency safe altitudes, leg closest divert field data, intersecting Victor Airways/VFR routes/IFR routes (for peacetime training scenarios), artillery impact areas, safe passage corridors, and low-level transition routes.

A.1.2. AMPA.

To ensure that modern tactical air operations are successfully carried out in the face of increasingly effective air defenses, meticulous mission planning and preparation is vital. Missions must be planned using accurate and up-to-date information from numerous sources and all information entered must be made available to other interested agencies. Due to the need for fast aircraft turnarounds and high sortie rates planning must take the minimum of time.

The UK proposed Advanced Mission Planning Aid (AMPA) is designed to assist in the planning and preparation of Harrier GR7 missions by:

- reducing both planners and aircrew workload. An 8 aircraft mission would take 30 minutes to plan from receipt of the task order.

- reducing pilot in-flight workload by transferring mission data to the GR7 Video-generated map display and the production of a mission briefing card.

- increasing effectiveness by providing more comprehensive mission plans made possible by giving planners better access to all relevant and up-to-date data.

- allowing mission feasibility to be initially examined before detailed planning is undertaken.

AMPA consists of text and graphics configured computer workstations, networked locally via an ethernet or more widely by a secure communications network. It is designed for use by a variety of users in mission planning centers, the Forward Wing Operations Center/Combat Operations Center (FWOC/COC), as well as in tents or cabins at Harrier field sites.

The graphics workstations will display maps of different scales, stored on optical disk, and allow information to be overlaid on

the map using the graphics capabilities. The user is able to zoom in to show greater detail and 'pan' over the map. AMPA can display five overlays simultaneously over the maps showing:

- intelligence information (SAM sites, FEBA, friendly force positions).
- route information (waypoints, initial points, fuel states and timings).

On receipt of the mission tasking order from FWOC/COC the route is planned by the entry of target position or patrol line, if there is no definite fixed target, waypoints, weapon load, speeds and heights and required time on target. A route is then generated that may be altered by the planner via the keyboard and mouse/trackball. The input of a few initial parameters allows the feasibility of the mission to be established and partial plans developed and passed between sites for development and multi-site tasking.

All fuel and speed calculations are made with reference to performance data held by AMPA on individual aircraft. Timings generated for individual aircraft take into account aircraft position in formation, type of turn and collision avoidance over the target.

A method by which AMPA speeds up the planning process is by referring to stored 'templates' of pre-planned attacks, formation turns and standard recovery procedures. Also referred to is information on possible threats that is used to produce a route of least risk by reference to terrain and threat data.

AMPA produces mission data in the form of:

- printed map(s) with overlaid information and Mission Briefing card containing specific mission information e.g., call signs.
- data for the avionics system via a data transfer unit consisting of
    - video map and overlays
    - waypoints and route information
    - action points, where the pilot is alerted to perform an action (e.g., in-flight report)
    - action points where the avionic system performs an action and informs the pilot (e.g., change radio frequencies).

The display by AMPA of imagery e.g., daylight photographs, FLIR pictures etc. allows aircrew to preview the appearance of specific points in the mission allowing a level of mission rehearsal to be carried out.

Post-mission reports, MISREPS, will be sent via the electronic messaging facility to FWOC/COC for evaluation, who will provide sites with an up-to-date database of intelligence, meteorological and NOTAMS. It may also provide route information to the proposed Automatic Low Flying Enquiry and Notification System.

The Advanced Mission Planning Aid allows full advantage to be taken of the increase in capabilities offered by the advanced avionics suites installed in the GR7 as well as in other aircraft such as the Tornado, giving and increase in both mission effectiveness and potential sortie rate.

A.1.3. AMPS.

The AMPS currently under development was initiated based on requirements of the US Army's special operations forces that in turn, have fostered significant interest within the Army's aviation community to the point of Mission Planning System (MPS) requirements for conventional Army aviation assets being formalized by the Training and Doctrine (TRADOC) Command.

TRADOC MPS requirements documents address two levels of mission planning capabilities, those at the Aviation Battalion and Aviation Company. In general the company level systems is a subset of the battalion system in that all the company capabilities can function at battalion but not all battalion functions can be done at the company. The overall salient operational characteristics as specified in the TRADOC requirements documents are detailed in the following paragraphs.

The aviation community requires a means of transferring tactical and operation data, developed prior to the initiation of a mission, into the airborne mission computer in a timely manner. The process is currently done manually which is time consuming and error prone. Army aviation assets are developing mass data transfer capabilities predicated on a small, portable, Data Transfer Cartridge (DTC) capable of transferring up to 256K bytes of data. The data is developed, formatted, and stored on the DTC by the MPS at both the company and battalion AMPS.

Performance planning is essential to the mission planning process in that it provides the ability to evaluate a specific aircraft's capability (physical and aerodynamic flight characteristics) to perform the designated mission over the battlefield terrain and enemy threat environment. The weight and balance computations are also essential, not only in the mission planning stages but also in subsequent stages of mission execution where aircraft load distributions have changed. The current methodology for accomplishing performance planning and weight and balance computations are manually labor intensive and time consuming. The MPS will automate these functions in the planning process and a subset of the MPS weight and balance capability will be implemented for airborne applications.

The aviator currently develops mission essential information such as, communications frequencies, navigation preference points, flight routes, etc. during the mission planning procedure and transcribes this information to a paper format that can be carried on a kneeboard for access during the mission execution. This form of the mission data is essential for those aircraft that are not capable for accepting a DTC and is also required as back-up reference for aircraft equipped to accept a DTC. The AMPS will provide data formatted in accordance with specified requirements for a variety of aircraft and will printout the necessary kneeboard forms.

The direct utilization of DMA products is necessary for mission planning in order to minimize the battlefield logistics support required to provide map and imagery products at the various echelons. DMA has standardized products available in the form of Compact Disk Read Only Memory (CD ROM) that will be used directly by the AMPS to provide Area of Interest (AOI) map, imagery, and various overlay data bases for planning purposes. The AMPS will support DMA's ARC Digitized Raster Graphics (ADRG) maps, SPOT Imagery, Level I Digital Terrain Elevation Data (DTED), Point Position Data Base

(PPDB), and other CD ROM based products as they become available.

Route planning is a primary function of the AMPS, and as such, the MPS must have the capability of supporting both manual and automated route planning functions. The automated route planning algorithm takes into consideration the terrain, threat, and mission objectives in planning a flight path. The system generated route is displayed as an overlay to a color background digital map so that the planner can fine tune and edit the flight path. The system automatically stores the pertinent mission parametrics associated with the selected flight path for utilization in other MPS functions, i.e. performance planning.

The airborne digital map requires a map and imagery data base in order to produce color images in the airborne environment. Typically, the area of coverage associated with a tactical mission, formatted in the DMA CD-ROM configuration used in the ground based MPS, requires hundreds of megabytes of memory storage in the airborne processor. Current weight and size restrictions for military aircraft preclude the use of such standard memory devices. Therefore, in order to implement an efficient, flight worthy, hardware suite the map and imagery data bases must be significantly compressed. This compression function is accomplished by the AMPS in a timely fashion and a suitable Data Transfer Module (DTM) is loaded with the data base for utilization by the airborne digital map system.

Mission rehearsal, especially real-time (flicker free CRT presentation) and fast-time (fast forward) fly through capability, is an essential part of the mission planning process. The out-of-cockpit perspective is necessary to familiarize the pilots with the ingress and egress terrain, the objective area, and in general what to expect in terms of terrain and surface features in unfamiliar areas. The AMPS will support real-time perspective view generation, for fly through mission rehearsal, through the utilization of Level I DTED for slope shaded perspective generation, photographic imagery draped over DTED, and ADRG topographic maps draped over DTED.

The AMPS will interface with the ATCCS Battlefield Functional Areas (BFAs) along with various battlefield and US national intelligence assets. The BFAs are Maneuver Control, Fire Support, Air Defense, Intell/Electronic Warfare, and Combat Service Support. Aviation is an arm of Maneuver and therefore the majority of the command directives and intelligence comes through the Maneuver Control System (MCS) at the Aviation Brigade level. Echelons below Brigade must interface directly to the individual BFA assets because of the current ATCCS architecture.

The mission planning process will, in addition to the tactical kneeboard forms, provide the aviator with topographic and photographic map imagery with the tactical data and flight routes depicted as overlays in color hardcopy compatible with the kneeboard size constraints.

The Aviation Battalion AMPS will be based on IBM compatible PC technology. The system design philosophy is to utilize an open architecture to take advantage of the availability of special purpose co-processing capabilities and the multitude of second and third party suppliers of PC compatible products. The basic processor will be supported by the following peripherals; full color scanner, digitizer tablet, communications interface, hi-res color and monochrome displays, full color/dot matrix printer, CD-ROM and read/write optical disk drives, and data transfer devices.

The Company MPS will be based on IBM compatible laptop technology. The basic design philosophy is to minimize weight and size to provide a man portable planning capability to the aviator. The Company AMPS will be housed in a transportation case that will also include an external flat panel display (optional), small dot matrix printer, and a data transfer device.

A.1.4. CAMPAL.

The Royal Netherlands Air Force (RNLAF) began working on computerized systems in the late 1970s, about the time it introduced General Dynamics F-16 aircraft in large numbers. It was believed that much of the capability of the modern aircraft was wasted if adequate command and control systems were not in place. NATO and individual nations were working on improved C^2 systems for use at levels above the airbase; the Netherlands decided to concentrate on the airbase level (notably OCA and CAS missions). The Computer Aided Mission Preparation at Air Base Level (CAMPAL) as available nowdays has been agreed to meet the requirements for support of the F-16 aircraft.

CAMPAL has been designed to operate as a subsystem of the Airbase Command and Control Information System (ABCCIS). The major objective of this interconnection is the provision of up-to-date, actual information by other ABCCIS subsystems to the CAMPAL system. The information is mainly a mode to act as a stand-alone system; in this mode, all mission relevant information is supplied from CAMPAL's own storage facilities, excluding tasking information (which is manually inserted).

The CAMPAL system also supports the tactical mission preparation process by various analysis tools including Enemy Defense Analysis Models (EDAM), Digital Terrain Analysis Models (DITAM), and Munition and Delivery Analysis Models (MADAM). EDAM yields effective ranges for enemy defense systems as a function of flight altitude and tactical conditions. DITAM presents terrain masking diagrams for defense systems with known coordinates. The MADAM package is an interactive weaponeering computer program, based on the Joint Munitions Effectiveness Manual (JMEM).

CAMPAL provides several additional functions including integration of all available intelligence data on enemy defense systems; an aircraft performance package that immediately evaluates the aircraft's capabilities and fuel requirements, generating the on-board computer data file that is transferred to the aircraft via the Data Transfer Cartridge; generating the flight plan (for peace-time missions), and generating the Combat Mission Folder.

Nowdays the CAMPAL system is in the preproduction state. As Mission Support System/CAMPAL (MSS/C) the system will be deployed by the Netherlands Air Force. MSS/C will also support other types of missions.

A.1.5. CINNA 3.

CINNA 3 is the newest mission planning system in the French Air Force. It is intended to be used for preparing multi aircraft missions. CINNA 3 is based on a SUN Workstation, its hardware includes: a high resolution color screen (1152 x 900), keyboard, mouse, 68020 CPU with floating point coprocessor, 16MB of RAM, a 527 2900MB hard disk, direct links to the aircraft and a color printer. Its capabilities include: the ability to display digitized maps; route planning using intervisibility calculations, fuel computation, planning the tactical approach

using spot images or 3D visualizations created from digital terrain data, and planning the attack. The system is designed to plan missions consisting of up to four aircraft. In the future, a mission rehearsal capability will be added that will allow the pilot to simulate the mission prior to take off.

A.1.6. CIRCE 2000.

Circe 2000 is an automated ground planning system intended for the French Mirage 2000N and Super Etendard. It provides the pilot the ability to select waypoints and navigation check points; performs flight profile, fuel consumption, timing, and weapons delivery computations; and provides the crew with digitized maps, terrain elevation data, tactical and weather data, and navigation points, that are linked to the system through a tactical network. The pilot interacts with the system using a keyboard, mouse, and menus. The Circe 2000 generates a variety of outputs including: color flight documents, aircraft plug-in memory inscription, and mission rehearsal. The system also provides intervisibility diagrams, and satellite views, and can be networked with up to 8 other work stations

A.1.7. MARPLES.

MARPLES is a mission planning system being developed for the Italian Air Force by Aeritalia. MARPLES (Military Aircraft Route Planning Expert System) is an expert system prototype for mission planning with an object-oriented data base and an user-oriented interface. The data base holds geographic and tactical information and gives inputs to the interface. A generator and an evaluator of likely paths are the main components of the data base. The main MARPLES' functions are:

- To display map information and to update the data base.
- To assist the pilot in planning the mission.

This function allows the utilization of the geographic and tactical information through (a) a map visualization, (b) inspection of its components, (c) an updating of its contents and, finally, (d) it allows to modify the structure of the data base. A description of these characteristics of the Map Display will follow.

The MARPLES interface is split into two windows: The map itself and the menu. By making connections among all the available tactical and geographical information, MARPLES is able to show the degree of risk that each area on the map presents (Color-coding is used to display degree of risk). In order to evaluate the degree of danger MARPLES takes into account relevant information like altitude and the pre-identified terrain points (such as waypoints, linear check points, threats). Map scale can be changed and the level of detail relative to any single area and/or terrain point on the map can be selected via menu.

The main purpose of MARPLES is mission planning, i.e., to help the pilot to choose the best route among the various possible routes. Mission planning through MARPLES consists of:

- Mission definition
- Mission planning and evaluation

Among the information that mission planners need in order to calculate best routes are:

- airfields
- task list: the goals to accomplish during the mission
- aircraft configuration
- fuel availability

By considering mission data, the mission planner calculates all likely solutions. The calculation takes place on the basis of a task-disentanglement principle and the overall task is subdivided into sub-tasks. All the sub-tasks are processed and calculated in parallel. As soon as this process has been completed a "task scheduler" triggers a process that combines the different local solutions (i.e., those concerning the sub tasks) in order to find global solutions. This process takes into consideration rules that allow rejection of local solutions.

At the end of this process many global solutions are available and the process of evaluation can begin. The evaluation process takes into account well-established criteria that allow selection of the most suitable route. To this aim bayesian algorithms are utilized. For any possible solution any parameter receives a weight at the global level and are referred to each other. Among these parameters the following can be mentioned:

- Risk exposure and acceptance
- Waypoint recognizability
- Amount of turn
- Initial point tactical evaluation
- Altitude profile
- Fuel consumption

At the end of the evaluation process a single global solution is displayed and suggested to the pilot as the best candidate for the mission. The other solutions are still available and the pilot is in charge of the final evaluation and decision.

This prototype can be considered as a first step for the realization and implementation of a fully developed expert system. Theoretical and practical work is in progress for the purpose of integrating this product with airborne systems and of rendering it flexible according to evolutionary tactical and environmental conditions and the pilot's style in planning missions.

A.1.8. TAMPS.

The Tactical Aircraft Mission Planning System (TAMPS) supports operational military planners for a variety of aircraft types and missions. It speeds the process of planning missions for both training and combat sorties. The system also provides a comprehensive analysis of penetration probabilities in complex defensive networks. The system software can be adapted to a variety of computer hardware, providing flexibility in meeting unique operational requirements.

The key objectives of TAMPS are to:

- provide a common mission planning system for rapid processing of large databases (terrain, environmental, weapon system performance, threat)
- perform interactive detailed trade-off analysis and digitally transfer data to/from supported weapons systems

- maximize reusability of government-owned software
- minimize new software procurements while meeting specific weapons system mission planning requirements
- provide evolutionary acquisition of incremental software releases and hardware installations.

Design of the TAMPS system is focused on improved exchange of information between the computer and the user. If the man-computer interface is designed to be user-friendly, the user can more easily control the direction and pace of the planning process by initiating specific actions. To accomplish this design goal, the computer software will be tailored to the unique requirements of planning functions and the software will use a plain English menu and prompts to eliminate the need for users to be training in computer or data processing. The TAMPS software is designed to provide:

- the capability to define aircraft routes by specifying turn points, speeds, and aircraft configurations
- an analysis of known threats relative to the selected mission route
- the capability to easily modify any part of an existing mission because of changing requirements or to reduce the probability of attrition
- a hard copy output data of the planned mission

The method used for route development is simple. The planner moves an electronic cursor on the color graphics screen to select locations for turn points and other essential mission actions. This cursor is connected to previously entered points by a line defining the aircraft ground track. A variety of graphic displays support the planning process and are easily selected at any point in the mission.

The interactive operation of TAMPS, using an alphanumeric (A/N) keyboard and digitizer tablet inputs, offers an easy alternative to manual mission routing and aircraft performance computations. Threat analysis is also provided to support routing decisions. TAMPS has automated the time consuming elements of analysis and calculation while keeping decision making under the user's control.

The Tactical Aircraft Mission Planning System will operate on the Micro VAX II computer system. The color graphics screen will be the focal point during planning. It is on this device that the mission will be constructed by displaying a wide variety of background pictures that provide information necessary to plan a successful mission. Terrain contours, threat locations, charts, and geography are examples of screen background content that might be used to lay in an appropriate ground track. As the route is built, an alphanumeric display will be updated to display the characteristics of the mission in a tabular form.

There are three input devices on TAMPS: a mouse, a digitizer tablet, and an alphanumeric keyboard. A graphics screen is used to display available function keys to the mission planner. By selecting a key name with the electronic cursor the appropriate function will be performed. The mouse and digitizer tablet are locator devices that position the cursor on the graphics screen. The alphanumeric keyboard is used to type a response to a prompt, usually on the alphanumeric screen.

A printer produces hard copy output of several alphanumeric formats. One of these outputs, the Flight Plan, is intended for aircrew use during the flight of the planned mission. A color copier produces hard copy output of any graphics terminal display.

The Tactical Aircraft Mission Planning System involves two inter-related tasks: database administration and mission planning. Prior to mission planning, the database administrator (DBA) creates all the databases needed during the planning process. Details of that task may be found in the Database Administration Operator's Manual.

The mission planner generates the ground track of the route, produces aircraft performance results, and analyzes environment. Personnel familiar with the basic elements of aircraft mission planning, navigation, threats, and/or flight dynamics will be best suited to use the system. Those with aircrew experience will quickly adapt. TAMPS is designed to make the planning process logical and straightforward with few special procedures. It is based on English language messages, queries, and responses; the use of selectable function keys; and terms and symbols familiar to the planning process.

A.1.9. TEAMS.

The Tactical EA-6B Mission Support (TEAMS) system was implemented to demonstrate the capability to expand TEAMS to accommodate the requirements of integrated strike warfare. To deliver maximum ordinance on target while increasing aircraft survivability the system must contain the following mission-essential functional characteristics. The system must be flexible, incorporating command structures and all platform requirements. The system must be fully integrated for coordination of all battle group strike components. The system must be quick and reactive to completely assimilate the latest tactical data and adoptive for response to service changes. The goal of the integrated strike warfare support system is to increase mission success and survivability.

TEAMS was designed specifically as an integrated hardware/software system to support the EA-6B strike warfare mission. On receipt of the strike planning order from higher authority, the strike planning board initiates the plan to strike the designated target(s). Strike planners must provide information to guide preparations. This information includes target identification and location, levels of damage (or number of weapons), desired routes, critical timing, and other constraints important to planning.

The TEAMS mission support system consists of the following elements that are integrated into hardware and software components. For threat preparation intelligence, training, and standard operating procedure doctrine data are accumulated. These data are used to derive tactical data and processes for area operations, support contingency planning, and high level tactical preparation. Depending on the strike targets and constraints imposed by the strike planner, specific strike preparation is initiated. Specific strike preparation consists of analyses of available data for geographics, threat analysis, route fuel planning, load out, and threat platforms and system capabilities. Results of these analyses are converted into flight plots and mission plan. A post-strike analysis is conducted that focuses on threat location damage, aircraft maintenance summaries, and correlation of data and functions performed to mission plans.

The mission support system is supported by graphics workstations that display a plan overview of the target objective. The work stations are configured with software algorithms that permit flexible exercise of the planning data in remote terminals

in the EA-6B ready-room suitable to pre-mission preparation. The ready room capability consists of texts and graphics outputs that are networked. Specific features of the workstation capability are the computation of, e.g., fuel, speed, and the critical timing of the plan to speed up and increase the pre-decision of the planning process, and a flexible graphics capability that provides rehearsal of the mission prior to mission execution.

A.2. EVALUATION OF AUTOMATED SYSTEMS.

The emerging mission planning systems that have been reviewed in this report represent a wide cross section of missions, aircraft, nations and capabilities. The intention of this sub section is to discuss and compare these mission planning systems in a manner that illustrates their similarities and differences.

The comparisons will be made for all of the mission planning systems reviewed previously in five categories.

(1) System Overview. Describes an overview of the mission planning systems that includes (a) information on the developer, user and application aircraft for each mission planning system and (b) a description of the mission planning capabilities of each system (route planning, intervisibility, weapons delivery and aircraft performance manuals).

(2) Hardware. Describes the hardware configuration of the mission planning system in terms of the computer and its data storage capabilities (hard disk, optical disk and tape).

(3) Database Capabilities. Describes what databases the mission planning system supports including terrain, satellite photography, intelligence data, operational data, weather data, pilot reports, radar imagery, FLIR imagery and communications information.

(4) Ergonomics. Describes the computer interfaces to the mission planning systems (mouse, trackball, joystick, touch screen), whether on-line help is available and whether the system can adjust the time required to generate a flight plan to respond to limited-time planning situations.

(5) Mission Rehearsal. Describes what mission rehearsal capabilities are available in the mission planning systems including whether the system supports 2D viewing, 3D viewing, variable speed simulation capability and dynamic events.

A.2.1. System Overview.

An overview of the automated mission planning systems is provided in Table A-1. For each mission planning system, this table provides: the developer of the system, the services that are using or supporting the development of the system, the aircraft that the system is designed to support, whether the system is ground based, ship based, or an airborne system, and whether or not the system is currently operational.

Developers. The development of the emerging mission planning systems has been performed by a combination of large, well established avionics companies (Aeritalia, General Dynamics, McDonnell Douglas, Ferranti) and by a group of smaller companies specializing in mission planning systems (Horizon Technology, Merit Technology, Command Systems).

Services. The automated mission planning systems are being developed for almost every service (army, navy, air force, marines) of every NATO country that was surveyed.

Applications. Mission planning systems are being developed for a wide variety of aircraft and aircraft missions as shown in Table A-1.

Basing Mode. All of the automated mission planning systems reviewed here have been designed for use on the ground or on-board a ship.

Operational Status. Approximately half of the mission planning systems reviewed are currently operational. However those systems that are operational are available in very limited numbers. The few systems that have been deployed are, for the most part, in the field for evaluation by operational forces. Those systems that are not operational, range from near operational levels to laboratory studies.

An overview of the mission planning capabilities of the automated mission planning systems is provided in Table A-2. For each mission planning system, this table indicates whether or not the system can support intervisibility and masking calculations for either ground-to-air (G-A) or air-to-air (A-A) threats, route planning, weapons delivery planning (where applicable), and on-line aircraft performance.

TABLE A-1. Overview of Emerging Mission Planning Systems.

System	*Developer*	*Service*	*Application*	*Based*	*Operational*
AAFMPS	Not selected	USAF	F-15, F-16, F-111, ATF, ATA	Ground	No
AMPA	N/A	RAF	Harrier GR7, Tornado	Ground	No
AMPS	Not Selected	USA	AH-64, OH-58, UH-60A, CH-73	Ground	No
CAMPAL	NLR	RNLAF	F-16	Ground	No
CINNA 3	MATRA	FAF	Mirage III, V, F1CR, Jaguar	Ground	Yes
CIRCE 2000	SAGEM	FAF	Mirage 2000M, Super Etendard.	Ground	Yes
MARPLES	Aeritalia	IAF	AMX	Ground	No
TAMPS	M. Douglas	USN	F-14,18, A-6,7, AV 8B	Gr/Ship	Yes
TEAMS	PRB Associates	USN	EA-6B	Gr/Ship	Yes

TABLE A-2. Mission Planning Capabilities of Emerging Mission Planning Systems.

System	*Intervisibility*	*Route Planning*	*Weapons Delivery*	*Aircraft Performance*
AAFMPS	G-A	Yes	Yes	Yes
AMPA	Masking	Yes	Yes	Yes
AMPS	Yes	Yes	Limited	Yes
CAMPAL	Yes	Yes	Yes	Yes
CINNA 3	In Progress	Yes	Yes	Yes
CIRCE 2000	In Progress	Yes	Yes	Yes
MARPLES	In Progress	Yes	No	Yes
TAMPS	G-A, A-A	Yes	Yes	Yes
TEAMS	Yes	Yes	Yes	Yes

Intervisibility. Most of the mission planning systems surveyed performed inter-visibility calculations for ground-to-air threats. Only three of the systems (and only one of the operational systems) performed intervisibility calculations for air-to air-threats.

Route Planning. Route planning was provided by all of the mission planning systems that were reviewed.

Weapons Delivery. Weapons delivery planning was provided by a majority of the mission planning systems and by most of the systems that were developed for fixed wing aircraft.

Aircraft Performance Manuals. All of the mission planning systems support on-line access to the aircraft's performance manuals. Performance information is required to assess fuel usage during the course of the mission and is therefore of critical importance. Any mission planning system that cannot provide this capability is of limited use.

A.2.2. Hardware.

An overview of the hardware used to implement the automated mission planning systems is provided in Table A-3. For each mission planning system, this table describes: the computer and storage capabilities of the system.

Computer. Almost all of the automated mission planning systems that were reviewed are implemented on computer workstations, the dominate choice being the Micro Vax II.

Data Storage Capabilities. All of the automated mission planning systems provided data storage capabilities using some combination of hard disk, optical disk and/or tape drive. All of the systems that were reviewed provided a hard disk. The size of the hard disks varied from a low of 80 MB to a high of 630 MB. Some of the systems provide an optical disk capability. The optical disk is used by most of the systems to store terrain data. Over half of the systems provide tape drives. The use of the tape drive seems to split equally between use as a primary data storage medium and as a back up device.

The capabilities of a mission planning system are directly tied to the number of types of mission data that it can access and process. In Table A-4, the data bases supported by each mission planning system are listed. The databases that were considered in this survey are digital terrain elevation data (DTED), satellite photography (Photo), intelligence data (Intel), operational data (Ops), pilot reports (Pireps), radar imagery (Radar), infrared imagery (FLIR) and weather data.

It is difficult to make any general conclusions about data base capabilities. With the exception of digital terrain data, none of the categories was supported by all of the systems. Most of the systems supported several categories of data but these categories varied from system to system. In general it appears as if each planning system supports only those data bases that are of primary importance to the mission for which it was designed.

TABLE A-3. Hardware Configurations of Emerging Mission Planning Systems.

System	*Computer*	*Hard Disk*	*Opt. Disk*	*Tape*	*Weight*
AAFMPS	N/A	Yes	Yes	Yes	N/A
AMPA	N/A	N/A	N/A	N/A	N/A
AMPS	386 PC	200 MB	600 MB	No	N/A
CAMPAL	N/A	N/A	Yes	N/A	N/A
CINNA 3	Sun Wrkst	527 MB	No	No	N/A
CIRCE 2000	N/A	40-150 MB	3-6 GB	No	130 Kg
MARPLES	Symbolics	370 MB	No	N/A	N/A
TAMPS	Micro Vax II	630 MB	No	TK50-AA	N/A
TEAMS	Work Station	2 450MB	Yes	9 track	680 Kg

TABLE A-4. Database Capabilities of Emerging Mission Planning Systems.

System	*DTED*	*Photo*	*Intel*	*Ops*	*Pireps*	*Radar*	*FLIR*	*Comm*	*Weather*
AAFMPS	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AMPA	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes
AMPS	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes
CAMPAL	Yes	No	Yes	No	Yes	No	No	No	No
CINNA 3	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No
CIRCE 2000	Yes	No	Yes	Yes	Yes	Yes	No	No	Yes
MARPLES	Yes	No	Yes	Yes	No	No	No	No	No
TAMPS	Yes	Yes	man	man	man	Yes	No	No	man
TEAMS	Yes	No	Yes	Yes	Yes	No	No	No	No

A.2.3. Ergonomics.

Ergonomics are an important part of any mission planning system. The primary benefits of a mission planning system (the ability to generate more effective mission plans in less time) cannot be achieved without a well designed user interface. Three ergonomic factors were reviewed for each mission planning system: the man/machine interface, the availability of on-line help, and the ability of the system to vary the time required to plan the mission to support situations where only limited time is available for planning.

Interface. The man/machine interface is one of the critical areas affecting ergonomics in automated mission planning systems. Of particular concern is the ability for the human operator to enter data and commands quickly and easily. To meet this requirement all of the new mission planning systems have supplemented the traditional keyboard interface to the computer, with a variety of pointing aids including the mouse, trackball, digitizer cross-hair, joystick and touch screen. Many of the systems offer a package of several pointing aids, adding flexibility to using the system. Pointing aids are particularly useful for mission planning because they can eliminate the need for entering latitude, longitude locations via the keyboard. This not only reduces the time required to plan the mission, but also reduces the likelihood of errors. Pointing aids also allow the user to interact with the system using menus instead of keyboard commands that reduces the amount of information the operator must memorize in order to effectively use the system.

On-line Help. All of the mission systems that were reviewed provide some form of on-line help to the operator, although the quality of that help was much more limited in some of the systems than others.

Variable Plan Time. All of the mission planning systems, with the exception of TAMPS, did provide some variable planning time capabilities. Again as with the on line help, some systems provided greater capabilities than others.

Mission Rehearsal Capability. The computer-based mission planning systems when combined with color graphics hardware make it possible to rehearse the mission via simulation. It is expected that this capability can dramatically enhance pilot performance during the execution of the mission. The mission rehearsal capabilities of the mission planning systems that were reviewed are displayed in Table A-6. Information is provided indicating whether each mission planning supports 2D and 3D (bird's-eye) views during mission rehearsal, whether the system supports a variable speed simulation (slower or faster than real time), and whether the system supports dynamic events during the rehearsal. All of the systems that provide mission rehearsal capabilities (about half of the total) support both 2D and 3D viewing during the rehearsal.

TABLE A-5. Ergonomics of Emerging Mission Planning Systems.

System	*Interface*	*On-line Help*	*Variable Plan Time*
AAFMPS	unspecified	unspecified	Yes
AMPA	mouse, trackball	Yes	Yes
AMPS	graphical, trackball	Yes	Limited
CAMPAL	trackball	Yes	Yes
CINNA 3	mouse	Yes	Yes
CIRCE 2000	mouse	Yes	Yes
MARPLES	mouse	Yes	Yes
TAMPS	mouse	Yes	No
TEAMS	keyboard and mouse	Yes	Yes

TABLE A-6. Mission Rehearsal Capabilities of Emerging Mission Planning Systems.

System	*2D View*	*3D View*	*Variable Speed*	*Dynamic Events*
AAFMPS	Yes	Yes	Yes	Yes
AMPA	No	No	No	No
AMPS	Yes	Yes	No	No
CAMPAL	Yes	No	No	No
CINNA 3	Yes	Yes	Yes	Yes
CIRCE 2000	Yes	Yes	Yes	No
MARPLES	Yes	No	No	No
TAMPS	Yes	Yes	Yes	No
TEAMS	Yes	Yes	Yes	No

Variable Speed. The ability to vary the speed of the mission rehearsal is very useful because it allows the pilot to "fast-forward" through mission phases where work load is low and to thus spend more time rehearsing the critical mission phases. About half of the mission planning system surveyed provided a variable speed mission rehearsal capability.

Dynamic Events. The capability to simulate dynamic events enables the pilot to rehearse "what if" situations (what if a threat pops up here, what if you lose an engine half way into the mission, what if the primary target changes in-flight). Unfortunately, only two of the planning systems (AAFMPS and CINNA 3) provides this capability.

The automated mission planning systems that are being developed to replace paper maps and grease pencils represent a major step forward for tactical mission planning. The new systems enable the pilot to plan a more effective mission, faster, and with less likelihood of error. In addition, the mission rehearsal features of the new systems enable the pilot to gain increased familiarity with the mission, before it is flown and to identify critical areas of the mission where workload may be high.

The new systems represent a major step forward, however, significant improvements remain to be made. Of particular importance is the requirement for moving mission planning systems from the ground and into the aircraft, but none of the emerging mission planning systems reviewed in Phase One is addressing this problem. In addition, the emerging mission planning systems need to improve their data base capabilities so that they can support a wider variety of the intelligence and operational data that will be available in future conflicts. In the NATO arena interoperability is a critical concern. As mission planning becomes more dependent on automated systems, it will become necessary for mission planning systems to support the mission planning needs of NATO aircraft of other countries, or else reduce the ability of the NATO air forces to operate out of any NATO air base.

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14. Abstract

The concept of planning a mission for a military aircraft is probably as old and well established as that of the military aircraft itself, but until recently the methodology and technology associated with mission planning had received only limited attention from scientists and engineers. The last few years have, however, seen a marked increase in the attention given to mission planning both by the users, who are demanding improved facilities, and by the suppliers, who are able to provide increasingly more capable systems. As a result, the air forces of many of the NATO countries are procuring new and advanced mission planning systems that have capabilities far in advance of those previously available.

This is an interim report of the AVP/AMP joint working group 5 mission planning systems for tactical aircraft (pre-flight and in-flight). A final report is anticipated in early 1993.

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